The implications of discount rate reductions on transport investments and sustainable transport futures

December 2009

NZ Transport Agency
research report 392

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ISBN 978-0-478-35265-8 (print)
ISBN 978-0-478-35264-1 (electronic)
ISSN 1173-3756 (print)
ISSN 1173-3764 (electronic)

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Parker, C (2009) The implications of discount rate reductions on transport investments and sustainable transport futures. *NZ Transport Agency research report 392.* 154pp.

Keywords: BCR, benefits, cashflow, cost benefit, costs, discount rate, evaluation, land transport investment, New Zealand, transport

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Acknowledgements

We would like to thank the NZ Transport Agency and our co-funders Roading New Zealand (Mr Chris Olsen), Downer EDI Works Limited (Dr David Hutchison), and Mr David Alabaster and Mr David Silvester of the NZ Transport Agency (previously Transit NZ). We are very thankful for the contributions of Nick Allison (previously of Hyder; now of the Ministry for Economic Development) and the support provided by Mr Ernest Albequerque, Mr Paul Clark and the research programme team of the NZ Transport Agency. We are grateful for the valuable support from Dr David Hutchison and Anthony Casey of the Treasury, and from the Ministry of Transport, particularly Ms Joanne Leung. In particular, we thank the wide range of approved authorities throughout the country that kindly allowed us access to their economic evaluations through LTP Online, and the input of Kai Chan of the NZ Transport Agency. We are thankful for the original letters of support given to the project by Maree McNeilly of the Auckland Regional Transport Authority and Joe Hewitt of the Greater Wellington Regional Council. We thank our peer reviewers Dr Stephen Gale of Castalia, Dr Tim Denne of Covec, Mr Ian Wallis of Ian Wallis Associates and Mr John Hallet of Beca; and also the support of Dr Mark Harvey of the Australian Bureau of Infrastructure, Transport and Regional Economics, and Dr Geoff Bertram of Victoria University of Wellington.

Abbreviations and acronyms

BCR	Benefit-cost ratio
CAPM	Capital asset pricing model
CBA	Cost-benefit analysis
CO_2	Carbon dioxide
EEM	*Economic evaluation manual* (NZTA publication)
LTMA	Land Transport Management Act
MRP	market risk premium
NBIR	Net benefit investment ratio
NLTF	National Land Transport Fund
NLTP	National Land Transport Programme
NPV	Net present value
NZTA	NZ Transport Agency
NZTS	New Zealand Transport Strategy
PV	Present value
SOC	Social opportunity cost
SPPWF	Single payment present worth factor
STPR	Social time preference rate
VOC	Vehicle operating costs
USPWF	Uniform series present worth factor
WACC	Weighted average cost of capital

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Executive summary

Introduction

This study was undertaken between 2007 and 2009 to assess whether a significant decrease in the discount rate used in cost-benefit analyses (CBAs) of initiatives partly or fully funded from the New Zealand National Land Transport Fund (NLTF) would significantly affect New Zealand's mix of land transport investments and the implications for the future land transport environment.

CBA is a method of evaluating the added benefits and costs over time to the whole of society from an initiative or set of initiatives relative to the status quo. Effects are expressed in monetary terms, even though they may not involve flows of cash or even have market prices, and the discount rate is used to convert these monetary impacts over time into a single present value figure.

While undertaking the research, the benefit-cost ratios (BCRs) of some projects were occasionally volatile, discontinuous and generally unintuitive. A separate review of the BCR formulation was undertaken within this study to understand the basis for such results, and to assess alternative formulations to determine if a more informative and consistent approach is possible.

Method

Scope

A review of discounting was undertaken and a range of plausible discount rates from 3–10% have been used to assess the impact of the discount rate on cost-benefit measures.

The CBA evaluations of over 150 projects across 11 project types that conform with the NZ Transport Agency's (NZTA) *Economic evaluation manual* (EEM) were collected, and each CBA was incorporated in a single spreadsheet model. The BCRs of each type of project were calculated for each of the discount rates within the range of 3–10%.

The review of the BCR formulation led to the identification of an alternative BCR formulation that was robust to variable discount rates, and allowed all BCRs to be informative and comparable. This formulation, known as the net benefit investment ratio (NBIR), weights operating and maintenance costs by the expected future cut-off BCR and includes them on the numerator rather than the denominator. This was judged to be theoretically robust and to be a more informative measure to use for the purpose of this specific study.

Key assumptions and limitations

- The focus of the study was on CBA results only, namely BCRs. However, BCRs may not adequately capture wider strategic imperatives and thus are only one factor in investment decisions. An indication of higher or lower priority for a type of transport initiative does not necessarily imply that more or less of those initiatives will be undertaken.

- The focus was on using existing cost-benefit appraisals that applied the EEM's methodologies. Some effects of the discount rate may be attributable to the particular methodologies used rather than the inherent attributes of the initiatives. Occasionally, it was difficult to understand the economic intuition behind certain methodologies, and recommendations have been suggested to refine those.
- No parameter values prescribed in the EEM were altered. However, the basis for some unit cost values may be implicitly based on the discount rate, such as the cost of carbon, the cost of crashes, and other health and environmental impacts that do not represent only immediate effects.
- The size of the available budget for funding transport initiatives was expected to remain constant or increase only modestly as the discount rate was altered.
- CBA results for initiatives are particularly influenced by the respective base cases. If a different discount rate leads to a different pattern of investment then, in the long term, the nature of the overall network may change, altering the properties of the base cases in future periods. Because of this, the data this research was based on may become less representative. Assessments of long-term impacts (25+ years) are conjectures based on whether changes could be expected to last indefinitely.

Results

The analysis highlighted the changing priorities that might result from a lower discount rate, which, because of budget constraints, could lead to more initiatives of certain types being undertaken at the expense of other types.

As lower discount rates are applied, the BCRs of projects increase, given the general pattern of costs and benefits over time. Unless this is accompanied by a significant increase in National Land Transport Programme revenues, the transport budget would become more constrained and, if used, higher cut-off BCRs would be required. A lower discount rate also favours projects that result in lower future operating and maintenance costs for government, where these costs are also subject to the budget constraint. The tighter budget means every dollar in the budget is more valuable: any increases in transport revenues or reductions in costs to operate and maintain the transport network correspond to greater proportional additional benefits from the additional projects that could be funded. Thus a project that releases an extra dollar of cost is valued more than any project that produces an extra dollar of benefit.

Table XS1 summarises the effects on different types of initiative under a significantly lower discount rate. Because these effects may change over time as the network progressively changes, the effects are described over differing periods of time. 'Short term' is taken to be a period of five years; 'medium term' is up to 25 years, which is about the design life on standard pavements; and 'long term' is 25+ years, but is split into periods of 25–60 and 60+ years (the latter is referred to as 'very long term'). It may take as much as 60+ years (depending on the discount rate reduction) for maintenance strategies to transition fully to a new steady state, whereby the levels of investment in maintenance become constant over time and aggregate cost savings can be fully realised.

Table XS1 Summary of possible effects on relative priorities from a lower discount rate

Initiative type	Short term (0–5 years)	Medium term (5–25 years)	Long term (25–60 years)	Very long term (60+ years)
Maintenance	++	++	+	-
Major capital works	++	++	+/++	+/++
Small to medium-sized works:				
• User benefit oriented	–	–	~	+
• Cost saving oriented	+	+	+	~
Public transport services (non-commercial)	–	–	~/–	+
Walking and cycling	~/–	~/–	~	+
Travel behaviour change	––	––	––	––

++ = large relative increase in priority
\+ = relative increase in priority
~ = no relative change in priority
– = relative decrease in priority
–– = large relative decrease in priority.

The general impacts on different types of initiatives are outlined below.

Maintenance-oriented initiatives

These are initiatives that largely govern future annual and periodic cost obligations to preserve a level of service to users of infrastructure.

- **Short to medium term:** these initiatives feel the greatest positive effect from a lower discount rate. However, a key cause of benefit is not from low discount rates directly, but from these initiatives saving money in the future and releasing funding demands on future budgets that would be more tightly constrained (at least in the medium term) in a lower discount rate environment. However, this is not expected to be sustained indefinitely.
- **Long term and very long term:** as the transport network improves in durability and quality, each initiative's CBA 'base case' would also be more robust, and the economic efficiency of further upgrades to the network would diminish.

Although many life-limited infrastructure assets, particularly pavements, are designed to last only 25 years, the new steady state may take two to three life cycles (perhaps 60+ years) to happen, depending on the change in the discount rate. Factors influencing this include:

- budget restrictions on maintenance to ensure enough funds are available for other types of initiatives
- the need to upgrade progressively so the quality of the network is balanced and future periodic rehabilitations across the network do not occur at about the same time.

Once this steady state occurs, the average annual cost to maintain and operate the network would probably be less in the steady state, all else being equal (even though the periodic rehabilitation cost may be greater).

Major capital works

Major capital works projects such as motorway construction, bridges and major road realignments increase in priority in the short, medium and long term because of the long-term net benefits generated. A lower discount rate increases the practical requirement to evaluate impacts more than 30 years out (if not the theoretical requirement, as this should be done anyway and the effects should be included in the appraisal as a residual value). However, evaluating impacts further out than 30 years raises potential issues with uncertainty and specifying credible scenarios over this time span (many of these problems are masked by the current 8% discount rate).

Whether relatively high BCRs for such works can be sustained indefinitely is uncertain. If realistic travel options to motorists can also be provided when major urban corridors are developed, particularly public transport services, then travel demand management initiatives such as congestion charging may be a viable alternative to further major capital works. This would reduce the case for sustained capacity expansion. Lower BCRs would result if these alternatives were included in CBA methodologies.

Small- to medium-sized capital works

These projects do not have shorter construction periods than major capital works, but the impacts are not as long lasting. Although their BCRs increase, these projects are likely to be somewhat crowded out by an increased focus on maintenance and major capital works. Within these projects, initiatives that have a strong cost-saving element will probably still retain sufficient priority to maintain or possibly increase their occurrence.

In the long term, the importance given to cost-saving initiatives may begin to decrease, freeing up more funds for initiatives that are user benefit oriented rather than cost oriented.

New public transport services

New public transport initiatives generally have ongoing operating and maintenance costs that occur over future periods that are large relative to the initial investment. While a lower discount rate serves to make such initiatives more economic at first, future operating costs are more heavily weighted, which offsets the extent to which BCRs increase (whereas this factor works in the favour of maintenance-oriented initiatives). Thus the relative priority of public transport initiatives is expected to be lower, all else being equal, following a material decrease in the discount rate in the absence of measures to access additional sources of funding.

Existing services are expected to be continued.

In the very long term (60+ years), the annual average cost to maintain the overall transport network may be lower, relieving the demands on the fund and possibly allowing more funds to be released to operate public transport services.

While beyond the scope of this study, revising particular unit cost values that are possibly a function of the discount rate, such as those that represent health and environmental effects, would contribute to offsetting the decline in relative priority, although just how much is not clear at present.

Cycling and walking initiatives

The BCRs for these initiatives have increased, but proportionally less than other initiatives. However, this could be largely attributable to the CBA methodologies used at present rather than underlying factors. For cycling and walking projects, the methodologies contained in the EEM lead to very few benefits in the initial years of operation, whereas other project types usually have significant benefits that are seen immediately. If benefit flows followed a more orthodox pattern – and it is not clear why they would not – then the relative ranking of such initiatives may not alter materially. (The benefit growth rates typically forecast for these initiatives were much higher than for other projects.)

Travel behaviour change initiatives

The BCRs of travel behaviour change initiatives have the lowest proportional increase in BCRs. This is caused by the absence of growth assumed in annual benefits. Although the effects are assumed to last for 10 years, and thus are not natural beneficiaries of a lower discount rate and a long(er)-term view, controlling for the shorter length life through an annual equivalent measure does not materially alter this result.

CBA assumptions and methods

A lower discount rate increases the importance of accurately specifying when and how large impacts occur in the future. Some simplifying assumptions currently made in practice include:

- constant linear growth rates
- no relative price effects over time
- a reluctance to model induced travel for major projects that have substantial construction timelines and thus delayed benefits
- low emphasis on valuing real options
- no change in automotive technologies (eg the widespread introduction of electric vehicles)
- controlling for mutually exclusive initiatives with lives of different lengths.

These assumptions should be reconsidered in a lower discount rate regime.

It is possible to improve comparability of the evaluations of maintenance initiatives, particularly pavement types. Evaluations of general investments should incorporate and recognise wider impacts to road users and take a longer-term view for any given discount rate. This is accomplished through altering the BCR formula and by improving the techniques around comparing initiatives with different lengths of life.

Managing transition

A transition phase will be associated with any alteration to the discount rate. A substantial reduction in the discount rate would increase the focus of the needs of transport users in the future and reduce the focus on the needs of transport users in the near term. The challenge is to maintain an appropriate balance between the needs of those using and paying for the transport system now as well as the needs of those in the long term, while maintaining a suitable weighting on CBA in overall investment decisions. The key consideration is identifying transitory effects that will not be sustained indefinitely, particularly increases to durability and quality, and managing those effects without unduly delaying the inevitable correction.

A material lowering of the discount rate may lead to investments that do not naturally align themselves with achieving the New Zealand Transport Strategy 2008's targets for 2040[1], particularly those relating to public transport and active modes. While a lower discount rate may improve the priority given to Roads of National Significance[2], the increased priority given to maintenance initiatives from a lower discount rate could restrict funding available for Roads of National Significance projects (as well as increasing the initial investment cost of these projects because their BCRs are higher if they have lower whole-of-life costs).

While some effects may not align with strategic policy objectives, alternative 'stretch targets' can be devised so that outcomes that do align with strategic policy objectives are advantaged by the lower discount rate. Specific targets could be developed relating to initiatives that lower whole-of-life costs, reduce the failure of infrastructure assets, reduce disruption to network users caused by maintenance activities, reduce average noise levels of key routes and reduce the amount of oil-based products used to maintain the network.

Measures that are compatible with economic CBA methodologies to manage the transition include:

- updating CBA methodologies so they are better at measuring and assessing the effects that are not captured by CBAs (such as environmental sustainability, improving access and mobility, and public health)
- temporarily expanding the budget from central government sources to partly mitigate the excess demand for funds (through increased taxation, borrowing or reprioritising)
- increasing funding from other sources such as tolls and debt financing
- developing an economic and policy framework that applies a leveraged BCR formula that increases the priority of initiatives when funds with a lower opportunity cost are offered from outside the NLTF.

Measures to manage the transition that deviate from pure economic CBA recommendations but do not totally discard CBA techniques include:

- developing an adjusted CBA framework (in addition to the existing CBA framework) that alters the significance of certain effects, such as:
  - requiring selected kinds of maintenance initiatives to underplay future cost-saving impacts
  - prioritising upgrades of key corridors over other network components
  - factoring up the impact of initiatives that are disadvantaged by the lower discount rate (eg raising the value of travel time savings and/or applying a proxy value to public transport initiatives for strategic option values from having substitute modes)
  - using a different discount rate for different initiatives

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[1] Examples of targets are:

- increasing use of public transport to 7% of all trips by 2040 (ie from 111 million boardings in 2006/7 to more than 525 million boardings in 2040)
- increasing walking, cycling and other active modes to 30% of total trips in urban areas by 2040.

[2] Described in the 2009 *Government policy statement on land transport funding*.

- separating certain activity classes unfavourably affected by a lower discount rate and allowing them to have lower average BCRs, and using BCRs for prioritising within those activity classes.

The third class of measures is to simply reduce the emphasis of CBA for certain types of investment activity and significantly increase the use of multi-criteria analysis.

The extent to which project proponents, appraisers and funders adhere to the altered CBA recommendations resulting from any significant lowering of the discount rate is perhaps most influenced by the buy-in that stakeholders have on the appropriateness of the updated discount rate. If any major reduction was deemed to be appropriate, then CBA would probably provide a greater influence in decisions than it currently does, moderating the role of multi-criteria analysis, and simplifying transport planning and strategy development. The extent to which CBA is judged to capture wider economic, social and environmental effects will remain the most important consideration, however.

Review of the discount rate

Two main approaches can be used to determine the appropriate social discount rate:

- the social opportunity cost of investment, on the assumption that government expenditure or policy requirements displace investments that would have earned a return
- the social opportunity cost of consumption, on the assumption that government expenditure or policy requirements displace consumption.

The former is commonly known as the social opportunity cost rate (SOC) and the latter the social time preference rate (STPR or sometimes SRTP). These rates cannot be reconciled in any simple way.

The use of the STPR for CBA is becoming much more widespread internationally and leads to (real, inflation adjusted) discount rates perhaps in the order of 3%–5%. The SOC rate is typically based on the capital asset pricing model (CAPM), and is the basis for setting the current 8% discount rate (previously 10%) used to evaluate initiatives partly or fully funded from the NLTF.

A major issue causing a difference between these two rates is deemed to be an allowance for risk. While many STPR advocates argue that economic risk is negligible across all of society, private displaced investments are still deemed to return around 8–10% per annum.

Significant difficulties arise in estimating either the SOC or STPR. The STPR has a degree of uncertainty and involves normative (rather than scientific) judgements about the value of the pure time preference rate and about properties of the social welfare function now and over time. CAPM specifications of the SOC rate do not assess impacts from a social perspective, but from the perspective of a private investor. Share purchases may not sufficiently represent the displaced private investments, and the use of the CAPM for determining the SOC rate can be undermined by the notion advocated by some welfare economists that no discernable level of social risk results from undertaking even the highest returning portfolio because of the limited impact individual projects have on aggregate consumption.

Given that the NLTF is now essentially funded from hypothecated transport revenues (fuel excise duty, road user charges, and motor vehicle registration and licensing fees) rather than corporate taxation, the raising of revenues is probably more likely to displace private consumption than displace private investment. The road user charges etc incurred by firms using the transport network arguably increase costs and may potentially lead to less private sector initiatives generally being undertaken, but this is probably immaterial and would probably fall within the margin of error of CBA. This would imply that the use of an STPR is appropriate and that therefore concerns about the SOC can be ignored in this specific context.

Concerns about specific NLTF-funded activities crowding out specific private sector initiatives can best be managed by good governance processes and informed use of CBA by the NZTA and approved organisations rather than wholesale lifting of the discount rate.

After considering some plausible values of the relevant parameters, the appropriate value of the discount may lie between 3–5% real, but the range may be wider than this. A mid-point value of 4% is appropriate, but the final decision should lie with policy makers rather than economists, given the normative judgements required.

A declining discount rate schedule could be considered. However, it is more important to resolve issues and concerns regarding how to evaluate the long-term impacts between 30 and 80 years before considering such modest refinements to the discount rate.

Review of the BCR formulation

The review of the BCR formulation recommends alteration of the BCR formula to the NBIR[3], which explicitly takes account of the expected nature of future budget constraints.

CBA theorists are generally reluctant to use BCRs on the basis that they change depending on what is defined as a cost or a benefit, a problem that does not apply to the net present value (NPV). However, BCRs are useful for ranking projects when budgets are constrained and not all NPV positive projects can be undertaken; undertaking the projects with the greatest BCRs until the funds are exhausted maximises the overall NPV from the constrained resource. The existing NZTA definition of the BCR is:

$$\frac{\textit{Present value of benefits less disbenefits to users}}{\textit{Present value of costs less cost savings to government}} = \frac{B}{IC + OC} \qquad \text{(Equation XS.1)}$$

where:

B = the present value of benefits less disbenefits to users

IC = the present value of investment costs

OC = the present value of operating and maintenance costs.

As the transport budget applies both to up-front investment costs and to ongoing operating and maintenance costs, the formula given in equation XS.1 appears appropriate. However, the use of equation XS.1 has the following issues:

- The formula cannot take any possible expectation that the future cut-off BCR might change into account.

[3] This criterion is described within this report as the comprehensive NBIR.

- The formula implicitly contains a specific value of the future cut-off BCR and assumes it equals itself (the resulting BCR of the project), which can potentially skew the interpretation of BCRs of competing projects in a multi-criteria funding environment when BCRs are only one factor in decisions.

The cut-off BCR represents the value of additional funds to the budget, and is sometimes known as the 'marginal BCR'. It is the ratio of additional total benefits resulting from a marginal expansion to the whole land transport budget. For example, a $10 million budget expansion that funds additional projects with $20 million in benefits implies a cut-off BCR of 2. That projects with BCRs greater than 1 are not being funded is an example of budgetary constraints and a cut-off BCR of some sort being applied.

The BCR formula in equation XS.1 implicitly assumes the existence of a future cut-off BCR that is constant over time and equal to the resulting BCR of the project.

If expectations of the future cut-off rate could be formed which show that this rate might change, this is not ideal. This is because projects that incur costs in what are expected to be relatively tight times are not appropriately penalised, and no premium is given to any initiatives that can be undertaken now that save costs when budgets are expected to be relatively tight. However, the uncertainties regarding the nature of future budgets and demands on budgets make forming any expectation of the future cut-off BCR difficult – let alone one that changes over time – and this alone is probably not sufficient to warrant a change in the formula.

The second issue is a more substantial problem: the existing BCR does not allow authorities to conclude that an initiative with a higher BCR than another (which is not mutually exclusive) is more economically efficient.

Because other factors also influence the NZTA's investment decisions, BCRs are only one component in decisions and are traded off against other factors. A project with a lower BCR might be undertaken at the expense of a higher BCR project, and thus no specific cut-off BCR is applied in practice. However, a cut-off BCR is implicitly being used by the fact that funding is rationed and projects are ordered on the basis of perceived overall net benefit per unit of funding, whether that benefit is measured in monetary terms or not.

The magnitude and comparability of BCRs are of critical importance to the NZTA's investment decisions. Some initiatives, such as public transport services, seal extensions, preventative maintenance and selecting pavement types have significant future cost components, and expectations of future budgetary conditions can have a large bearing on their perceived economic efficiency. If the BCRs of such projects differ widely, then widely different assumptions of future budgetary conditions are made under the existing formulation. In order to allow the BCRs of all such projects to be compared and traded-off against non-CBA factors, it is important that the CBAs of each make consistent, if not the same, assumptions about future budgetary conditions. Because BCRs often range from less than 1 to well over 50, assumptions about future budgetary conditions can vary wildly; for projects with significant future cost components, this leads to incomparable BCRs. This is not a problem inherent to the evaluation of projects with relatively large investment costs, such as major roading projects, because future operating and maintenance costs have a negligible impact on their BCRs.

An alternative BCR formulation that overcomes these issues is the NBIR (equation XS.2), which differs by including future costs on the numerator and takes account of future budget constraints by factoring those costs by the assumed future cut-off BCR.

$$\frac{\textit{Present value of benefits less disbenefits to users, less operating costs to government factored by the assumed future cut-off BCR}}{\textit{Present value of investment costs to government}} = \frac{B - \mu \cdot OC}{IC} \qquad \text{(Equation XS.2)}$$

where:

B = present value of benefits less disbenefits to users

IC = the present value of investment costs

OC = the present value of operating and maintenance costs.

μ = the assumed future long-term cut-off BCR, the factor by which operating and maintenance costs are multiplied to reflect the opportunity cost of funds in the future.

Such a change would require the NZTA to prescribe values of the future cut-off BCR to apply in evaluations. While this would be a challenge, the use of even a probable rule-of-thumb value would do much to improve the comparability of BCRs across all projects. However, the value needs to be well considered because it can have a large impact on the BCRs of projects with a significant future cost components.

Conclusions

This research indicates that the public sector discount rate materially influences the portfolio of investments in land transport. A substantial lowering of the discount rate, given the historic use of using a 10% discount rate, will lead to a very large emphasis on upgrading the quality and durability of the network to reduce whole-of-life costs. With fixed budgets, this could crowd out much investment in new infrastructure and public transport services for a significant period of time. This would give rise to the need for initiatives that facilitate sustained increased funding to the system, and for strategies to help ensure that the needs of future users and funders are not given excessive priority over users and funders now and in the near term as a result of having used a 10% discount rate for about four decades.

We recommend that the following actions be taken regardless of any treatment of the discount rate:

- extending the baseline appraisal periods for large projects to the extent that is supported by formal modelling
- issuing guidance on the ‘rolling over’ method for mutually exclusive initiatives with lives that differ in length
- altering the BCR formula to the NBIR formula, which includes centrally prescribed assumptions of the future cut-off BCR
- improving guidance for appraising maintenance strategies to capture how road users and externalities will be affected while the NBIR is in use
- improving the valuation of third party revenues with lower opportunity costs than NLTF resources (leveraged BCR formulae)
- improving knowledge acquisition by voluntarily uploading CBA data from EEM software for research purposes.

Other actions are advised, as they recognise the need to test the sensitivity of the discount rate and to determine the best estimate of present value benefits and costs incurred:

- undertaking sensitivity testing of the discount rate
- developing approaches to extend appraisal periods credibly past what is currently supported by formal modelling
- improving questionable CBA assumptions that are masked by the current high discount rate and thus support meaningful sensitivity testing of the discount rate
- considering – and, if needed, improving guidance on – how parameter values may change if the social discount rate were tested for sensitivity.

A third class of actions is advised to alter the value of the discount rate and the considerations necessary to support this value:

- agreeing on a framework for basing the public sector discount rate upon the STPR, or some combination of the STPR and the SOC
- issuing guidance regarding the impact of shadow pricing on the private sector, where necessary
- reviewing governance processes to ensure that a lower discount rate will not lead to undue crowding out of private sector transport initiatives
- reviewing policies and legislation to determine options for obtaining sustained increases in funds to the land transport sector
- revisiting strategic transport objectives to develop alternative ‘stretch targets’ advantaged by a lower discount rate
- reviewing strategic transport policy and evaluation frameworks to ensure that the transition towards a new system equilibrium is managed appropriately
- adjusting CBA methodologies in order to maintain or improve the influence of CBA by ensuring that the methodologies capture the ‘softer’ impacts that are not properly accounted for at present.

We strongly advise that the first two sets of actions should be undertaken regardless of any consideration of the default or baseline discount rate.

Abstract

The effects of reducing the discount rate used in evaluations of initiatives funded from the National Land Transport Fund (NLTF) were assessed during 2007–2009. Over 160 projects across a range of project types were collated and the relative effects of different discount rates were documented.

As lower discount rates are applied, the demands on the budget become greater, and every dollar in the budget becomes more valuable. Thus any project that releases an extra dollar of cost is valued more than any project that produces an extra dollar of benefit. A lower discount rate would probably be most favourable to initiatives that reduce the total cost of maintaining and operating the network, and are favourable to major long-lasting infrastructure investments. Initiatives with large future operating and maintenance costs decrease in relative priority. The NLTF is now funded from hypothecated transport revenues, so raising revenues is more likely to displace private consumption than private investment. Therefore, using a social time preference rate is most appropriate. This might range from 3–5% real rather than the current 8% real, with 4% being appropriate. However, the final decision should lie with policy makers rather than economists, given the normative judgements required.

1 Introduction

This study assessed whether a significant decrease in the discount rate (used in cost-benefit analyses (CBAs)) would lead to significant effects on New Zealand's mix of land transport investments and the implications for the future land transport environment. This will further inform the debate as to what the appropriate discount rate should be, and to provide transport stakeholders with knowledge on the effects of a reduction, so they can respond appropriately.

The research objectives were to:

- find the range of plausible discount rates using different theoretical models
- assess the plausibility of a range of possible discount rates for altering the nature and mix of New Zealand's land transport investments
- evaluate how this changing mix of investments, and the nature of those investments, bequeaths future generations a sustainable transport future
- provide workable policy advice on how stakeholders could best respond to the effects of a range of lower discount rates
- provide policy advice as to what the appropriate rate should be, taking sustainability effects into account.

The study took place between 2007 and 2009, and used data from over 160 cost-benefit evaluations undertaken when the discount rate was 10%. The data includes projects relating to maintenance, new and improved roads, public transport infrastructure, cycling and walking, and travel behaviour change projects to assess the relative effects of altering the discount rate.

2 Background

2.1 Chapter overview

This introductory chapter briefly describes CBA, the basis of discounting and the key decision criteria[4]. This gives a context to certain terms and key issues that will be used in the report.

2.2 The role of CBA

Social cost-benefit analysis, or CBA for short, is a method of evaluating the added benefits and costs over time to the whole of society from an initiative or set of initiatives. The potential initiative could be an investment, a policy, a regulation, a tariff or subsidy, or any other proposal[5]. The evaluator seeks to assess the overall benefit to society and to prioritise the initiatives and others by evaluating the pros and cons of each action for all of society's stakeholders relative to the status quo.

Effects are expressed in monetary terms, even though they may not involve flows of cash or even have market prices, and they are measured by comparing the results of the initiative against what would probably have happened if the initiative did not occur (the counterfactual).

Time is a key consideration: competing initiatives usually have different, if not substantially different, profiles of costs and benefits over time. The evaluator must trade greater social benefits in the future off against more modest benefits that occur earlier. The public sector discount rate, through a process of discounting, is the parameter that governs this trade-off of effects across time.

Issues pertaining to the very long term (ie 60+ years) are growing in prominence internationally, eg global warming, stratospheric ozone depletion, loss of biological and ecological diversity, and long-term energy security. As a result of this, the standard approach to discounting is coming under increased scrutiny.

2.3 Use of the discount rate

The NZTA's (2008) *Economic evaluation manual* (EEM) introduces discounting by noting that the community places a higher value on benefits and costs that occur in the near future, compared with those that occur at a later date. Thus it is not possible to directly compare the value of effects occurring at different times.

[4] The interested reader can refer further to the EEM (NZTA 2008), Treasury NZ (2005), Bureau of Transport and Regional Economics Australia (BTRE) (1999), and the suite of Australian Transport Council (2006a and b) National Guidelines documents, as well as to CBA textbooks. The BTRE is now known as the (Australian) Bureau of Infrastructure, Transport and Regional Economics.

[5] CBA is not limited to justifying government investment; desired initiatives can come about through policy levers to elicit other entities to undertake the initiative, such as taxation, subsidisation and regulation.

If the consumption of one dollar's worth of a resource is deferred and invested at an annual interest rate of, say, 10%, this will yield $(1 + 10\%)^{10}$ dollars' – \$2.59 – worth of roughly equivalent resources in 10 years' time. Thus the impact of \$2.59 a decade from now corresponds to only \$1 today if the discount rate is 10%.[6]

Benefits (and costs) occurring in time *t* are conventionally discounted as shown in equation 2.1:

$$PV(B_t) = \frac{1}{(1+r)^t} B_t \qquad \text{(Equation 2.1)}$$

where:

PV = present value

B_t = benefit at time t

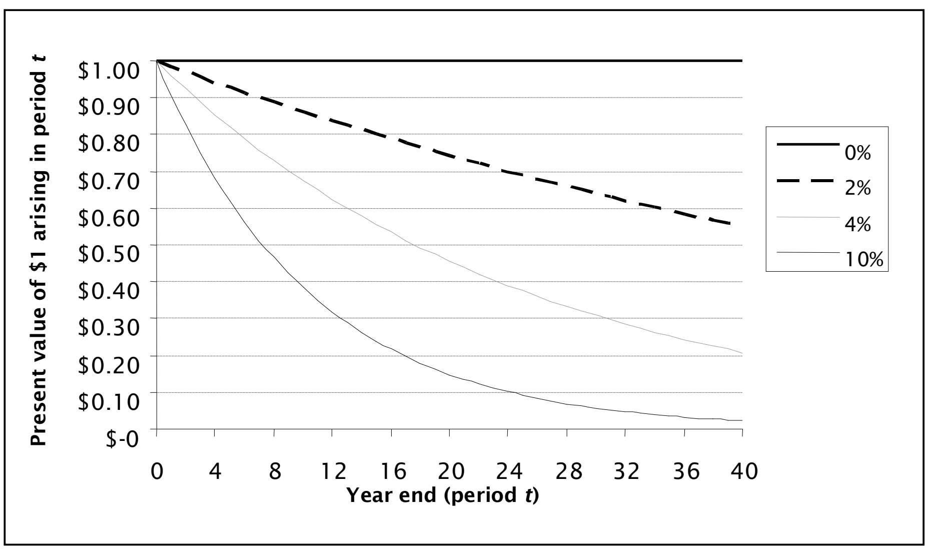
r = discount rate (the derivation of this is discussed extensively in chapters 3 to 10).

The lower the discount rate, the greater the inclination will be to defer consumption and investment, and vice versa.

Impacts and discount rates are typically valued in *real* terms (prices today) as opposed to *nominal* terms (prices at the time the goods or services were provided). So a 10% discount rate when inflation is 3% leads to a nominal discount rate of approximately 13%.

Compounding discount rates can have a dramatic effect on the present value (PV) of costs and benefits in the future. Figure 2.1 shows the present value of \$1 in the future against a range of different discount rates. For instance, every \$1 of benefit in 30 years' time is valued as \$0.06 now at a discount rate of 10% p.a. compounding (geometrically). At a discount rate of 4%, this value is five times higher at \$0.31.

Figure 2.1 Effects of compounding discount rates over 40 years



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[6] While most generally agree about this statement in short to medium timeframes (25–30 years), very long-term considerations are more debateable (eg Portney and Weyant 1999, especially Lind 1999).

The effect of lowering the discount rate normally increases the BCR of a project because costs normally precede benefits (ie a project has no decommissioning costs). The initial investment costs of projects that start immediately are generally not affected by discounting, even at higher discount rates; however, benefits and future maintenance and operating costs are subject to potentially heavy discounting. A high discount rate is less unfavourable to projects with shorter payback periods than to projects with longer term benefits and/or cost reductions.

In September 2008, the real discount rate to use in land transport investments was reduced from 10% to 8%, following a review by the Treasury (Treasury 2008), and the maximum analysis period advised in the EEM was lifted from 25 years to 30 years. The EEM does not recommend that effects occurring after 30 years be included in the evaluation, on the basis that they are not material by virtue of the discount rate. At a discount rate of 8%, $1 in 30 years' time has a present value of only about $0.10.

Given that the analysis period is based upon the discount rate, lowering the discount rate should increase the analysis period.

2.4 Cost-benefit decision making criteria

2.4.1 Net present value (NPV)

Two primary methods for summarising the results of CBA and informing decisions are the net present value (NPV) and the benefit-cost ratio (BCR).

The NPV of an initiative is simply the sum of all benefits and costs, as shown in equation 2.2:

$$NPV = \sum_{t=0}^{n} \frac{B_t - OC_t - IC_t}{(1+r)^t} \qquad \text{(Equation 2.2)}$$

where:

t = time in years

n = the number of years during which benefits and costs occur (could be set to infinity)

r = the discount rate

B_t = the monetised net benefits (gains in welfare to society) in year t

OC_t = infrastructure operating costs in year t (resource costs)

IC_t = investment costs in year t (resource costs).

The Treasury primer (2005) favours the NPV method, but acknowledges the regular use of the alternative BCR in evaluating roading projects. The major limitation with the NPV criterion is that it is not very suitable when considering a constrained resource, so not all NPV positive initiatives can be undertaken.

2.4.2 Benefit-cost ratio (BCR)

The BCR measure is used to rank a large number of initiatives where a resource is constrained[7]. In a budget-constrained situation, the overall NPVs of the all investments are maximised by undertaking initiatives in descending order of BCR ranking, until the budget is exhausted (assuming the cost of projects are small relative to the size of the budget).

Pages 11–14 of volume 2 of the EEM uses a definition of the BCR which is shown here as equation 2.3:

$$BCR = \frac{present\ \ value\ \ of\ \ national\ \ economic\ \ benefits}{present\ \ value\ \ of\ \ costs} \qquad \text{(Equation 2.3)}$$

where:

national economic benefits	=	net direct and indirect benefits and disbenefits to all affected transport users plus all other monetised impacts.
present value of costs	=	project capital costs + project operating costs + changes in road maintenance costs - deferred capital cost on other roads.

Chapter 11 of this report reviews equation 2.3 in response to the observation that the BCRs of some projects were occasionally volatile, discontinuous and generally unintuitive when the discount rate was lowered.

2.5 The cut-off BCR

The BCR of the project that just missed out on funding is equal to the *cut-off BCR*, and is a measure of the extent to which the budget is constrained. This is also known as the *marginal BCR*, and is discussed at length by the Australian Transport Council (ATC) (2006a and 2006b). It is a measure of how social benefits may increase if the resource was marginally expanded. This is further explained in section 10.2.2.

The ATC (2006b) explains that the level of the cut-off BCR over time depends on the balance between the demand for infrastructure spending and the supply of available funds. The cut-off BCR rises if funding for transport infrastructure fails to keep pace with increasing demand, changes in the locations of population and economic activity, and replacement needs of existing infrastructure.

If, for example, the land transport cut-off BCR was 4, then an increase in land transport investment of $10 million leads to $40 million in additional benefits; a net return of $30 million. Releasing $10 million in 10 years' time also corresponds to $40 million in present value benefits at year 10 if the cut-off BCR were still 4. The cut-off value can also be back-calculated if it was known how much greater (or less) the benefit to society would be from an expansion (or contraction) of the transport budget. This is a key measure of the extent to which the budget is binding and is a major element of this study, given the assumption that the budget will not expand – or at least will not expand as quickly as BCRs rise.

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[7] The constrained resource might not just be financial, but could be capital or other resources such as water (Travers Morgan 1995). In the context of the NZTA's investments, the constrained resource could broadly be conceived as the National Land Transport Fund, plus the contributions from local and regional government in accordance with Financial Assistance Rate policies.

A BCR of 4 or more was generally required in the latter part of the 1990s in order to obtain funding, and was higher previous to this (see table 2.1 below). However, a well-defined cut-off BCR no longer exists. This is because CBAs have diminished in influence over land transport funding decisions in New Zealand over the past decade because some effects cannot be measured and assigned a monetary value easily or with enough certainty.

Table 2.1 Historic values of the cut-off BCR (taken from Travers Morgan (1995))

Year	Local roads	State highways	Safety	Passenger transport
National Roads Board				
87/88	3.5	3.5	-	-
88/89	1.9	1.9	-	-
89/90	1.5	1.5	-	-
Transit New Zealand				
90/91	4.5	4.5	5.0	3.5
91/92: initial	10.0	10.0	8.0	10.0
after extra $13.3m	8.0	8.0	6.0	8.0
92/93	5.0	5.0	5.0	-
93/94	5.5	5.5	5.5	-
94/95	5.0	5.0	5.0	-

Although no well defined cut-off BCR now exists, the EEM still uses values between 2 and 4 as targets for incremental assessments, values that the ATC (2006a) argues should based on the cut-off BCR. Also, although no cut-off BCR is presently used nor is forecast, it is quite likely that any budget expansion would correspond to additional projects that have BCRs materially greater than 1. It is not the existence of any literally defined value of the cut-off BCR that is of importance; rather, it is the notion that benefits must correspond to costs on more than a 1:1 ratio because of the scarcity of resources relative to the higher demand for those resources.

3 Review of the social discount rate

3.1 Introduction

This chapter and the following five chapters of the report review the literature on social discount rates[8] used in CBAs and document the range of discount rates that can be justified on a sound theoretical basis using alternative frameworks. Models used to estimate the social discount rate can generate a wide range of values. However, technical specifications of the models cannot ultimately choose the discount rate: it should involve a wider policy judgement that considers key theoretical considerations, social and environmental outcomes, and effects on present and future generations. Normative/moral factors are arguably important, and including them – or avoiding them – cannot be judged on positive (rather than normative) grounds.

The objectives of these chapters are to:

- describe the basis of discounting in a cost-benefit appraisal (chapter 3)
- describe the key theoretical approaches to determining the social discount rate (chapters 3, 4 and 5)
- describe the basis for determining values of the social time preference rate (chapter 4) and the social opportunity cost rate (chapter 5)
- review the issues affecting the choice of discount rate (chapter 6)
- review international social discounting practice and recent trends (chapter 7)
- review the applicability of declining discount rates for assessing effects in the very long term (chapter 8)
- provide a summary and recommendations of how the New Zealand public sector discount rate should be set, and establish a range of discount rates that can reasonably be applied to land transport appraisals (chapter 9).

3.2 Social discounting

Given that a CBA is a social analysis, it requires a discount rate that reflects society’s value of time rather than one reflective of private investors (although the two could coincide). Depending on the timeframe considered, the spectrum of discount rates advocated by researchers can be immense, particularly for long-term considerations[9].

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[8] The term ‘social discount rate’ is used to describe discount rates used in social cost-benefit appraisals generally. The term ‘public sector discount rate’ is used to describe the government-mandated discount rate to use in public sector evaluations.

[9] Weitzman (2001) surveyed professional PhD-level economists from across the globe asking for their ‘professionally considered gut feeling’ of the real discount rate in evaluating global climate change initiatives. With 2100 useable responses from some 48 countries, the responses ranged from -3% to 27%, with a mean of 4% and a standard deviation of 3%, indicating substantial variation in judgement. The top 50 economists had the same mean and standard deviation. Extreme responses of less than 0.5% or more than 12% were recorded if the respondent

An adaptation of Spackman (2002) describes some of the reasons why a public authority needs to take account of how cost and benefits are spread over time when evaluating an action:

- The utility that people enjoy from a marginal dollar declines as they become richer.
- While most people care about future populations, most care less about distant populations than about those closer in time.
- The resources used to produce a subsequent benefit might instead be invested elsewhere to produce a smaller net cost or a larger net benefit.
- In addition to project-specific risk (which should be considered case by case), there may be some non-negligible chance that the future cost or benefit would not actually occur or would at the least be substantially and unpredictably altered. This could be because of some natural or man-made catastrophe, such as an asteroid collision, epidemic, war, or a nuclear or biological attack, which would not normally be considered explicitly for individual projects.

Discounting processes, as discussed below, can normally take account of these considerations. The following sections review current arguments and contexts for determining the social discount rate to be used in CBA.

3.3 Determining the social discount rate

Two leading schools of thought on how to determine the social discount rate exist:

- the social time preference rate (STPR)
- the social opportunity cost (SOC) rate.

While, in theory, the two concepts can lead to the same value being used, in practice, the STPR is much lower than the SOC. The concepts are defined as follows:[10]

The **social time preference rate** is the rate at which consumption in one period can be substituted for consumption in the previous period without any change in overall wellbeing. In other words, it is the rate of return r needed to make no difference to society between consuming x today and $x(1 + r)$ in the next period.

The **social opportunity cost** rate is the rate that reduces the NPV of the best alternative private use of the funds to zero (Young 2002).

The SOC typically reflects the cost in financial market terms and measures the opportunity cost of locking up capital in public sector assets. This leads to an approach where the government accounts for what 'similar' projects would provide in returns if undertaken in the private sector.

A key argument for using a SOC rate is that if private investments return, say, 10% (regardless of why they might earn 10%) and a potential public sector investment has a lower 'rate of return' than this, then society would be better off by investing those resources in the private sector. A similar argument holds for

responded with any remotely plausible story and held a PhD degree in economics from a recognisable graduate school.

[10] Sourced from Young (2002), Spackman (2002) and BTRE (1999); adherence to these definitions is common.

the STPR: if the STPR was, say, 5%, and a potential public sector investment has a lower rate of return than this, then society would be better off by simply consuming the resource.

A third approach is to consider a weighted average of the SOC and STPR to take account of the source of the resources, be it from forgone investment or consumption, as well as to take account of what consequent use can be made of the benefits that have been consumed or reinvested. The major issue relates to the uncertainty about which weights to use in the weighted average; these weights will not be the same for every project (Young 2002). Also, this approach still requires appropriate values of the STPR and SOC.

A fourth approach relates to factoring costs upwards to reflect the marginal productivity of capital and then discounting the adjusted cashflows using the STPR. This is discussed further in section 6.3.2.

Since the 1970s, the SOC approach has dominated in New Zealand as a benchmark for the public sector discount rate. Young (2002) says that 'any positive net present value achieved using a social opportunity cost discount rate should lead to the same result when using a social rate of time preference discount rate.'

Concern remains over whether:

- using a SOC rate leads to socially optimal outcomes when projects are ranked within a budget constraint
- claims relating to initiatives' supposed rates of return and the choice of discount rate are always valid and meaningful when initiatives have quite different patterns of benefits and costs over time.

Internationally, thinking has shifted significantly away from the SOC approach in recent times.

4 The social time preference rate

4.1 Issues with the STPR

It is debatable whether the STPR can be observed from market interest rates or whether it should be constructed using theoretical considerations. Some also argue that even if the STPR cannot be observed from market interest rates, market interest rates should still be adopted as the second-best proxy for the unobserved STPR. If market interest rates were adopted, this would lead to a social discount rate in the order of 4% (real).

Market interest rates are based on collective lending and borrowing by individuals within society. It would be tempting to base the social discount rate on the revealed time preferences of society as a whole and to use the (risk-free) government long-term bond rate to evaluate actions of a similar duration. However, many welfare economists are against such an action, at least in a purely theoretical sense. The key problems that may prevent market interest from representing the STPR in the first instance are:

- The STPR is a normative concept; observed behaviour is a positive concept. Thus the two are fundamentally incompatible (Arrow (1995), Feldstein (1964) and Pearce et al (2003)).
- The market has many imperfections, both in the market for loanable funds and throughout the economy (Organisation for Economic Cooperation and Development (OECD) (2007) and Feldstein (1964)). Market prices often give a misleading signal of value as a result and thus do not reflect the 'shadow price' or society's opportunity cost of the resource.
- Individuals cannot borrow at the government borrowing rate and they have a huge range of interest rates to choose from in reality (Spackman 2002 and 2006). In the ubiquitous presence of asymmetric information, individuals face many costs and constraints for borrowing and lending.
- Human behaviour may not be as straightforward as many economists judge it to be. Examination of private time preferences using a range of behavioural experiments (Frederick et al 2002) suggests that interest rates may be a very weak indicator.
- Markets do not fully reflect the preferences of generations in the distant future (if at all). Current markets, such as long-term bond markets, may reveal something about the preferences of the present generation regarding future generations. However, even these markets do not (because they cannot) reflect the preferences of a generation which is not yet born (OECD 2007).

Thus the STPR may differ from individuals' time preference rates, particularly when evaluating major investments and policies that have an effect over long periods of time, a lifetime or longer. In that case, the STPR would have no equivalent observable market rate. However, a well recognised alternative approach (shown in equation 4.1)[11] aims to break down the STPR into separate components, which may allow further insights to be made (Treasury UK 2006):

$$r = \rho + \eta g. \qquad \text{(Equation 4.1)}$$

[11] Variations to this formula have been suggested to account for risk, eg Weitzman (2007).

The STPR (r) has two components. The first is the rate at which individuals discount future consumption over present consumption, on the assumption that no change in per capita consumption is expected; this is represented by ρ (Treasury UK 2006). The second term represents society's preference for consumption to be smoothed over time and is based on two parameters:

- η – the elasticity of marginal utility of consumption with respect to utility
- g – the expected annual growth rate of consumption per capita.

We will describe the two components in more depth.

4.2 Elements of the STPR formula

4.2.1 The first term: ρ

This comprises two elements:

- catastrophe risk, L
- pure time preference, δ.

These elements are additive ($\rho = L + \delta$). Equation 4.2 shows a revised formula for the STPR:

$$r = L + \delta + \eta g. \quad \text{(Equation 4.2)}$$

4.2.2 'Catastrophe' risk, L

The first component, catastrophe risk, is the likelihood that a devastating event will occur so that all returns from policies, programmes or projects are eliminated, or at least radically and unpredictably altered (Treasury UK 2006). Examples are technological advancements that lead to premature obsolescence, or events like natural disasters and major wars. A (probably very small) positive utility discount rate would account for these risks. The scale of this risk is, by its nature, hard to quantify. One estimate of L based on the United Kingdom death rate leads to an estimate of about 1%. Stern et al (2006) used a value of 0.1% based on an analysis of table 4.1 that determines the likelihood of human survival in 10 years' time and 100 years' time, given a range of values for L.

Table 4.1 Effects on probability of human extinction from varying values of *L*

Values for catastrophe risk, *L*	Probability of human race:			
	surviving 10 years	not surviving 10 years	surviving 100 years	not surviving 100 years
0.1%	99.0%	1.0%	90.5%	9.5%
0.5%	95.1%	4.9%	60.7%	39.3%
1.0%	90.5%	9.5%	36.8%	63.2%
1.5%	86.1%	13.9%	22.3%	77.7%

Stern et al (2006) comment that for L = 0.1%, humanity has a 9.5% chance of extinction by the end of a century. The authors write that this figure 'seems high – indeed if this were true, and had been true in the past, it would be remarkable that the human race had lasted this long.' A figure of 1% for *L* would imply a 9.5% chance of extinction within 10 years.

The argument presented by Stern et al, while bold, is in the context of long-term climate change effects that some predict will devastate parts of the world. In terms of land transport investment, this parameter should be more modestly interpreted as a risk that is not modelled on a project by project basis. Interpreting *L* in this wider and less profound way may lead to higher values for *L* being applied.

4.2.3 Pure time preference, δ

The second component, pure time preference, reflects individuals' preference for consumption now rather than later, with an unchanging level of consumption per capita over time. This is an area that some philosophers and economists dispute: is it ethically defensible for society to value benefits more now for no other reason other than the mere passing of time? Many notable economists have argued that it is not ethically defensible (Ramsey, Pigou, Harrod, Koopmans, Solow and Cline. Refer to Arrow (1999)).

The arguments for having a small or zero value of δ become stronger and more numerous when long-term issues such as climate change are in question. These issues are characterised by their effects on future generations in the long-term (say a century) or very long term (multiple centuries) (see, for example, Oxera (2002)).

Arguments against having too small a value of δ is that to do otherwise would require society to save an extraordinary amount of resources now for future generations – a transfer of wealth from current generations to future generations on an excessive scale (Arrow (1995; 1999) and Pearce et al (2003)). However, Stern et al (2006) note that this concern is true of low values of the social discount rate, *r*, but not necessarily of the subcomponent pure time preference, δ. The value of *r* may be much greater than zero even if δ equals zero, which could be caused by high values for *L* and μg; the latter is discussed in the sections that follow.

It would seem then that determining a value for δ on a sound empirical basis is not possible because of its arguably normative overtones. A key consideration would be distinguishing between short-term actions pertaining only to one generation and longer-term actions that will affect future generations. This issue will be further discussed near the end of this chapter.

4.2.4 The second term: ηg

Intuitively, the second term is analogous to the optimal savings model of an individual whereby individuals have diminishing marginal utility, averages are preferred to extremes, and people prefer to smooth consumption over time rather than fluctuating between consuming large and small amounts.

Across time, an individual will borrow when they expect their income to be greater in the future than that at present, and will save when they expect their future consumption to be lower than at present. When the individual borrows, their revealed time preference at that moment is negative; when they save, it is positive (assuming no imperfections such as liquidity constraints). Thus an individual's saving and borrowing behaviour depends on at least two things: their expected future consumption and the degree of diminishing marginal utility.

This rationale underpinning an individual's choice of trading off saving and consumption is extended to the society's choice of saving and consumption. This approach contributes to determining the STPR and is comprised of two elements:

- elasticity of marginal utility of consumption, η, with respect to utility
- the expected annual growth rate of consumption per capita, *g.*

It is important to note that this approach requires a subjective judgement about how to aggregate the utility across society.

4.2.5 Elasticity of marginal utility of consumption, η, with respect to utility

The elasticity of marginal utility of consumption is a measure of the curvature of the utility function. If the utility function was linearly related to consumption, η would equal zero.

Pearce and Ulph (1999) summarise how one may determine the elasticity of the marginal utility of consumption, η. The traditional assumption underlying the STPR is that the utility to be gained from the stream of consumption $C = \{C_0, C_1, \ldots C_t \ldots\}$ takes the additively separable form shown in equation 4.3

$$W(C) = \sum_{t=0}^{\infty} (1+\rho)^{-t} U(C_t) \qquad \text{(Equation 4.3)}$$

where:

ρ = the discount rate

U(C_t) = the flow rate of utility accruing to society in period *t* from consumption in period *t*

W(C) = the net present value of future utility.

The elasticity of the marginal utility of consumption η is a measure of the percentage rate at which the marginal utility falls for every percentage increase in consumption – a measure of responsiveness. This is shown formally in equation 4.4:

$$\eta = -\frac{C \cdot U''(C)}{U'(C)} > 0 \qquad \text{(Equation 4.4)}$$

In general, the value of η will depend on the level of consumption, *C*. However, a widely used form of utility function is one for which η is independent of the level of *C*. This is the *iso-elastic* utility function shown in equation 4.5:

$$U(C) = \frac{a}{1-\eta} C^{1-\eta} \qquad \text{(Equation 4.5)}$$

The formula for marginal utility is given in equation 4.6:

$$U'(C) = aC^{-\eta} \qquad \text{(Equation 4.6)}$$

Pearce and Ulph (1999) describe two approaches for obtaining estimates of η:

- The first is to regard the elasticity of marginal utility of consumption, η, as reflecting the views of individuals about how they wish to transfer consumption across time. In this case, we try to infer values of η from observations on individual savings behaviour while imposing some restrictions on the underlying utility functions.

- The second is to regard η as reflecting society's judgement about how we should transfer consumption across people at different times. In this case, we think of η as telling us about how much more worthwhile it is to carry out transfer of income from a rich person to a poor person depending on how well off the two are. This approach can be used to broadly check the findings, and will be discussed further below.

Alternatively, η can be described as the coefficient of relative risk aversion (Weitzman 2007). Risk aversion can be modelled via concave utility functions, with greater risk aversion represented by greater concavity of the utility function. This approach provides a very different basis for determining η.

Pearce and Ulph (1999) show that savings models relevant to United Kingdom conditions point to a value for η of 0.8–0.9, with a value of η = 1 being defensible. Cowell and Gardiner (1999) similarly suggest that most estimates based on savings behaviour are fairly consistent and imply values for η 'just below or just above one'. They look at evidence drawn from the United Kingdom personal tax system to see what social decisions might imply about η as a social inequality aversion parameter. Cowell and Gardiner suggest that this work implies a range of 1.2–1.4, and that experimental work produces values of around 4. They conclude that 'a reasonable range seems to be from 0.5… to 4. Oxera (2002) argues that values such as 4, however, imply a quite dramatic degree of inequality aversion and demonstrates this with the following example.

Consider two individuals, one rich (*R*) and one poor (*P*), with utility functions of the form shown in equation 4.7:

$$U_i = \frac{Y_i^{\;1-\eta}}{1-\eta} \qquad \text{(Equation 4.7)}$$

where:

$i = R, P$.

The ratio of the two *marginal* utilities is given by equation 4.8:

$$\left[\frac{Y_P}{Y_R}\right]^{\eta} \qquad \text{(Equation 4.8)}$$

Suppose, just for illustration, that the income of the rich individual is 10 times that of the poor one, $Y_R = 10 Y_P$. The range of social values is shown in table 4.2, corresponding to various values of η.

Table 4.2 The ratio of loss in utility by the rich individual to the gain by the poor when wealth is transferred at the margin

η =	**0.5**	**0.8**	**1.0**	**1.2**	**1.5**	**2.0**	**4.0**
Loss to *R* as a fraction of gain to *P*	0.31	0.16	0.10	0.06	0.03	0.01	≈0

This shows that at η = 4, the social value of extra income to *R* is zero. At η = 1, a marginal unit of income to the poor is valued at 10 times the marginal gain to the rich. At η = 2, the relative valuation is 100 times. In this illustration, then, values even of η = 2 do not seem reasonable. Overall, looking at the implied values of η in savings behaviour and at the illustration above, values of η in the range 0.5–1.2 seem reasonable. Oxera (2002) use values of 0.8 –1.1 for η in most of their study.

Weitzman (2007), on the other hand, argues that in the economics of uncertainty, plausible values of the coefficient of relative risk aversion, η, for individuals are commonly taken to be somewhere between 1 and 4 (as a rule of thumb, Weitzman uses the geometric-average point estimate $\eta = 2$). Weitzman believes that η should also equal about 2 for society as a whole. This issue would take us down the path of whether society treats risk differently than individuals do, which is discussed in later sections. The point to note is that higher values of η may justifiably be used.

4.2.6 Expected annual real growth rate of consumption per capita, *g*

Estimates of the future annual growth rate of consumption per capita, *g*, are difficult to obtain, particularly in the timeframes used for land transport investments evaluations. For New Zealand, the average real annual gross domestic product per capita growth rate between 1948 and 2006 was approximately 1.4%, calculated using the gross domestic product series from Hall and McDermott (2007) and five-yearly census data. A value of 1.5% is used in the long-term fiscal model used by Treasury.

Two points should be noted. The first is that the marginal (instantaneous or year-specific) STPR need not be a constant: if reliable forecasts of the growth rate, *g*, could be formed that were cyclical and negative in some years, then the marginal STPR would vary and could occasionally be negative for some years. That aside, the average growth rate is positive and the average STPR will be positive also.

The second is that some policies that are the subject of a CBA, particularly climate change policies, may themselves alter the growth rate. Therefore, the overall STPR has an endogenous component and cannot be predetermined. This was the case for assessments such as the *Stern review* (Stern 2006). Arguably, the choice of even the public sector discount rate itself broadly influences *g*, and thus would influence the value of the underlying true STPR.

4.2.7 Assessment of the STPR

To summarise, the formula for the STPR is given in equation 4.9:

$$r = (L + \delta) + \mu g. \qquad \text{(Equation 4.9)}$$

As discussed above, it can be difficult to determine each of the elements, and different assumptions can lead to widely varying values of the STPR. None of the elements needs to be stationary in time, either. We have already mentioned that η and *g* could vary with time, depending on the model parameters used, and the ‘catastrophe’ variable *L* could vary with, say, expectations of international conflict (against New Zealand or possibly against key trading partners). In addition to this, hardly any research has been carried out in New Zealand and an analyst would need to rely on international research that may not be overly relevant to New Zealand purposes.

This uncertainty of future discount rates may lead the reader to judge that the discount rate to be used should be raised in accordance with the higher potential variability or risk. However, Weitzman (1999; 2001; 2007) shows that uncertainty about the future discount rate leads to a lowering of the certainty of the equivalent discount rate that should be applied rather than increasing the rate. This is discussed later.

In the United Kingdom, the STPR is used at a value of 3.5% based on $\rho = 1.5\%$ (presumably $\delta = 0.5$ and $L = 1$), $\eta = 1$ and $g = 2\%$.

Possible values of each parameter for the New Zealand case are represented in table 4.3 based on the ranges and rationales of each study referred to in section 6.2. The medium estimate arguably has a reasonable judgement of each individual parameter:

- δ = 0.5, which is significantly above zero
- *L* = 0.6, corresponding with a probability of 0.06 that benefits in 10 years will not eventuate for reasons that are not project-specific
- η = 1.25, reflecting that we do not appear too averse to redistributing wealth
- *g* = 1.5, representing New Zealand's low GDP per capita real growth rate.

Such parameters would result in an STPR of 3%.

Table 4.3 Possible range of the STPR for New Zealand

Estimates	δ	*L*	η	*g*	*r*
Low	0	0.1	0.7	1	0.8
Low-medium	0.2	0.3	1	1.4	1.9
Medium	0.5	0.6	1.25	1.4	2.9
Medium	0.5	0.5	1.5	2	4.0
Medium-high	1	1	1.5	2	5.0
High	2	1.25	2.5*	2	8.25

* Scobie (1980) estimated this as 2.5.

We should note that values lower than this are defendable, particularly the choice of 0.0 and 0.1 for δ and *L* respectively, which would result in a discount rate of 2.0% if η = 1.25 and *g* = 1.5%. Heal (2008) recently argued that the chance of Armageddon (*L*) is 'small enough to be neglected. However the point seems to be valid conceptually,' and that 'my own judgement is that the right rate of pure time preference is zero… but I have never actually been tempted to do so'.

Given the economic uncertainty being experienced over 2008 and 2009, it is not outside the realm of possibility that expected real GDP per capital growth could be negative for some time. A value of *g* equalling -1.0 would lower the 'low' STPR to -0.6, but could only be applied to those years experiencing the negative growth and would be revised upward for cashflows in subsequent years.

5 The social opportunity cost rate

5.1 Calculating the SOC

The SOC approach for determining a social discount rate is based on the returns in the private sector. The key argument for the SOC rate to be used is that if a public investment yields a lower overall benefit than a private investment, then society is better off with the latter. Since projects are evaluated more favourably when a lower discount is used, evaluating public investments with a lower discount rate might give them an unjustified advantage. It has been argued that if government projects fail to yield as high a return as private investments, total welfare would be increased if resources were channelled to the private sector.

Historically, opportunity costs were also expressed as the lost opportunities to, or, more precisely, the displacement of, the private sector as a consequence of public sector activities (Marglin 1963). Castalia (2006a) notes that since the advent of open economies, these specific concerns are no longer valid. These arguments are described further below. However, a poor distinction is often made in the literature between what *would* have happened versus what *could* have happened, which may partly contribute to the very wide range of views on the topic.

The aim of deriving the SOC discount rate is to use the same discount rate that the private sector would use when evaluating the investment, which is based on what they would earn elsewhere.

The only pragmatic approach to obtaining the SOC discount rate we have identified in our literature review is to use the capital asset pricing model (CAPM), which feeds into a weighted average cost of capital formula (WACC).

The reports by Young (2002), Perold (2004) and Castalia (2006a), particularly section 2.2 of the latter report, provide good summaries of the method of calculating the SOC using the CAPM. The Castalia report forms the basis for the explanation below.

Companies generally use the CAPM to calculate a WACC. They seek to invest only in projects with expected returns that are greater than the WACC. These projects enable them to pay their investors – both debt and equity – the returns they expect after tax.

The formula used to calculate the WACC depends on the tax regime. In New Zealand, the WACC, which is an after-tax measure, is given by equation 5.1:

$$WACC = (1 - T_c) R_d W_d + R_e W_e \qquad \text{(Equation 5.1)}$$

where:

T_c = corporate tax rate

W_d = debt/(debt + equity)

W_e = equity/(debt + equity)

R_d = pre-tax cost of debt for company = R_f + debt premium

R_f = risk-free interest rate, generally the government bond rate over a suitable timeframe

R_e = cost of equity capital to company = $R_f(1 - T_i) + \beta_e{*}MRP$

T_i = individual tax rate

β_e = equity beta, which measures the risk to equity relative to that of the market as a whole

MRP = market risk premium, which is the reward over and above the risk-free interest rate for bearing risk in a project of average risk – as seen in a market portfolio.

The formula gives the WACC to be applied to unlevered cashflows (ie cashflows that do not include interest payments but include tax as an expense). A company earning this return on assets (after tax) will be meeting its investors' requirements – just. A company earning more than this return is adding value to its shareholders. The WACC is a post-tax concept.

The WACC formula can be converted to a simpler form, which is independent of gearing. This formula is shown in equation 5.2 and is expanded in equation 5.3.

$$WACC = (1 - T_c)R_d W_d + R_e W_e \qquad \text{(Equation 5.2)}$$

$$WACC = (1 - T)\cdot(R_f + debt\ \ premium)\cdot W_d + (R_f(1 - T) + \beta_e MRP)\cdot W_e \qquad \text{(Equation 5.3)}$$

As $\beta_e = \beta_a/W_e$ (where β_a = the asset beta, the measure of risk to assets relative to the market as a whole, and T is the dominant 30% tax rate), the nominal WACC is described by equation 5.4 because the debt premium is small.

$$WACC = (1 - T)R_f + \beta_a MRP \qquad \text{(Equation 5.4)}$$

Using i as the expected inflation rate over the relevant period, the real WACC (inflation adjusted) is given by equation 5.5:

$$\left|(1 + (1 - T)R_f + \beta_a MRP)/(1 + i)\right| - 1 \qquad \text{(Equation 5.5)}$$

Thus the WACC, which in this instance is equal to the SOC, is based on two elements: the after-tax real risk-free interest rate and a risk premium. The after-tax real risk-free interest rate is generally in the range of 1.5–2.5%. The risk premium is comprised of two factors:

- *MRP*, the risk premium to the private sector which is based on the high volatility of the market
- the coefficient, β_a, indicating the correlation of the returns of a similar instrument with that of the market.

Section 5 of Castalia (2006a) calculated that the market average WACC, and thus the SOC, as 7.0% real, and 9.8% nominal. Castalia based this on the September 2005 PricewaterhouseCoopers report, the latest available at that time, and was based on a risk-free interest rate of 6.0% and an MRP of 7.5%, which implies an average asset beta of 0.77 using equation 5.5. Expected inflation was calculated to be 2.6% based on the difference between the government's inflation indexed bond rate to 2016 and the government's bond rate to 2017.

The Allen Consulting Group report (2004) uses market evidence from Australia and elsewhere to determine the asset betas of the (toll) road infrastructure sector. Table 5.1 is taken from their report.

Table 5.1 Observed betas for road infrastructure assets (from Allen Consulting Group (2004))

Company	Asset beta	Equity beta*
Macquarie Infrastructure Group	0.19	0.48
Hills Motorway Group	0.19	0.48
Transurban Group	0.25	0.62
Average	0.21	0.53

* Equity betas have been delivered assuming a zero debt beta and re-levered using a 60% gearing level (debt to assets). The asset betas are calculated assuming a zero debt beta. Note that Macquarie Infrastructure Group has toll road investments in several countries.

Using a value of 0.21 for the asset beta would lead to an **SOC of 3.5% real** using the Castalia formula. However, the risk on toll roads may not be reflective of risks on roading investment generally. In particular, such sectors will have a degree of 'self-selection' (cherry-picking) and will shift risk from private to public entities. Arguably the shadow betas for public investment could be significantly higher.

Lally (1998) advised Transfund (a predecessor to the NZTA) on a suitable discount rate for evaluating roading projects. Lally used a pre-tax specification of the WACC and estimated it as

> *[ranging] from about 9% real to 15% real, with a tentative estimate of around 12%. These numbers seem large, but reflect the denominator adjustment for company tax, which increases the discount rate by about 50% and serves to compensate for the absence of company taxes.*

Pre-tax WACC specifications of the SOC rate are discussed further below.

5.2 The Treasury's update of the public sector discount rates

Treasury's discount rate review (2008) has revised the public sector discount rate for the transport sector down from 10% to 8%.

The revision to 8% is based on values of 7% for the MRP, 30% for corporate tax, 6.4% for the risk-free rate, 3% for inflation and an asset beta of 0.65 for infrastructure, resulting in a **post-tax WACC of 5.9% real**. The Treasury, however, advocates for a pre-tax WACC, which inflates this value to about 8%. The key reason for the drop from 10% to 8% appears to be that the nominal WACC is 'grossed up' by an effective tax rate of 20% rather than 30%. Were it grossed up by a 30% tax rate, it would be 9.6%. The lower effective rate is based on the following:

- Tax concessions in the New Zealand tax code exist (such as the research and development tax credit (ruled out by the current government)).
- It is acknowledged that some offshore transactions have a low tax rate (viz the approved issuer levy).
- A figure of 20% has been used previously[12].

[12] The specific circumstances with which it was used previously were queried, but were not available.

5.3 Pre-tax or post-tax WACC?

A pre-tax WACC is calculated by dividing the nominal post-tax WACC by 1 minus the effective tax rate. A tax rate of 33% lifts the nominal public sector discount rate by 50%, a tax rate of 30% lifts it by 43% and a rate of 20% lifts it by 25%.

The government does not pay tax on the economic returns of its investments, but the private sector does pay tax on the financial returns of their investments. Concern is commonly raised that for certain activities, the public and private sectors contest to undertake an activity and the sectors should have a level playing field. That is, the government agency should not allow the fact that it has a tax advantage to crowd out private sector activities. Grossing the WACC up by a 30% corporate tax rate would scale up the above 7.6% (real) and 10.4% (nominal) to 12% and 15% respectively. Lally (1998) notes the following two points:

> *…government departments and TF* [Transfund, a predecessor to the NZTA]*, are not subject to company taxes. Without correction for this, these untaxed entities would generate larger valuations for a given project than taxed entities. Arguably this is not a concern – company taxes cause under investment, and untaxed entities in the public sector should not make the same error. However government has chosen to impose company taxes on many public sector entities, and to increase departmental costs of capital to compensate for* [their exemption from company taxes (p3)]. *This indicates a desire for consistency with the private sector.* (p6)
>
> *So consistency is desired, and requires* [Transfund's] *cost of capital to be 'grossed up' for the absence of company taxes.* (p3)

Castalia (2006a) agrees that where substitution between the public and private sectors is an issue that the public sector discount rate should be raised 'towards the grossed up WACC – to a greater extent the higher the degree of substitutability between the public and private sectors.' Young (2002) notes that the WACC 'needs to be adjusted to reflect that the government does not pay tax or get a tax break on paying interest,' but does not outline the economic case for that. The Treasury review (2008) notes that all public sector discount rates are to be based on the pre-tax WACC, based on the following arguments:

> *We note, however, that using a pre-tax rate of return is equivalent to taxing public sector investments* (p2).
>
> *The usual approach is therefore to estimate the expected return from alternative investments in the private sector, since that is likely to be a good proxy for the Crown's cost of capital (subject however to grossing up the cost of capital for corporate tax,* ***thereby generating similar decisions on project acceptance or rejection to those of the private sector****)* (pp2–3; emphasis added).
>
> *A public sector project either displaces a private sector project, or it has to be paid for by increasing the tax burden on the private sector. A discount rate equal to the pre-tax private sector rate of return therefore seems appropriate* (p4).

If the raising of the public sector discount rate to include tax is only done to alter the behaviour of agencies to ensure their investments do not inappropriately displace the private sector, as indicated by the quotes above, then some serious questions need to be asked about its wholesale application across government CBAs. This pre-tax formulation may be appropriate in particular circumstances, particularly when particular initiatives could be undertaken by either the public sector or the private sector. However, applying a pre-tax WACC to all government activities, particularly land transport, looks to be a rather simplistic prescription, and could accidentally bias investment away from initiatives with a longer-term focus. If the appropriateness of public versus private investments is a concern, many ways exist to deal with this issue other than manipulating the public sector discount rate. The discount rate should not be used as a proxy for solving poor government decisions and CBA should not be used only to justify government investment.

5.4 Some issues with using a financial economics framework to estimate the SOC

The BTRE (1999) notes that the marginal rate of return on private investment should be measured from a societal perspective, but that the social rate of return on private investment can differ from the private rate earned by investors. Such differences are hard to quantify.

The authors have the following broad concerns with the use of the CAPM and WACC to determine the SOC:

- It is uncertain whether the approach sufficiently (or at all) captures effects that are wider than just financial returns to investors, such as consumer surplus and any (unpriced) positive and/or negative externalities.
- Possibly, the purchase of shares by government (or by private citizens resulting from reduced taxation) could just be a transfer of ownership with no additional initiatives undertaken by the firms, and the funds given to the previous owner of the shares could just be consumed by them rather than reinvested.
- It is also unclear whether the additional initiatives undertaken because of the share purchases sufficiently conform to the rules applied in CBA. For instance, the timeframes of the additional private initiatives need to be sufficiently comparable to the initiatives being explicitly appraised in the CBA, and we have no assurance that they are. Also if the share ownership represents a programme of initiatives undertaken over time by those firms, rather than a single initiative, then it is at risk of not being comparable either, as all initiatives should be given the same opportunity to accrue benefits. One might consider a firm as an entity that undertakes a sequence of multiple projects.

These issues are of importance to cost-benefit practitioners and they have not been clarified in the literature. Their oversight could lead to the SOC rate being significantly mis-specified.

6 Issues affecting the choice of discount rate

6.1 Key questions

The difference in results between the SOC and STPR approaches can be very large, depending on the parameters used, and is primarily attributed in the literature as compensation for undertaking a risky investment. The STPR allows for catastrophe risk (risk that is not modelled on a project-by-project basis)[13], but the SOC has an order of magnitude larger allowance for risk based on the market risk premium. This will be discussed below.

Other key questions are:

- What is the effect of using a discount rate that is lower than that used by the private sector?
- Is forgoing these 'higher' returns really in society's best interest?
- Would the government crowd out private sector activity if it used a discount rate substantially lower than the private sector and what circumstances govern this?
- Is this approach to discounting appropriate when considering intergenerational outcomes? Do we have workable and justifiable alternatives?

6.2 Inclusion of risk premium

6.2.1 Defining risk

Spackman (2002) observes that practitioners cannot reach a consensus on whether a general public sector discount rate should include any factors for risk. The usual academic convention for welfare economics is to exclude risk from the public sector discount rate.

It is becoming standard practice internationally to exclude such risk factors from the discount rate used in social CBAs and to address risk by other means (refer to chapter 7 on international practice). One particularly strong advocate for this approach is Australia's BTRE (1999 and 2005). However, in practice, it may be more convenient and easier to defend the rate if the different kinds of risk are clearly recognised and if some are explicitly included in the rate.

The arguments of the BTRE underpin this section of the review.

To address the issue of risk, the BTRE first defines the components of risk as follows:

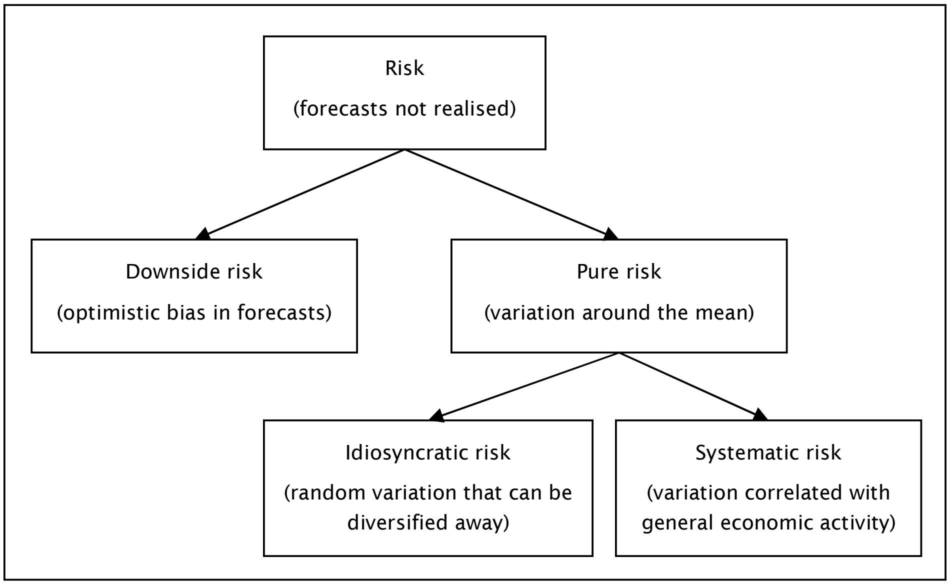
- downside risk, which arises from optimistic bias in forecasts
- pure risk, which is the variation remaining around the mean after removing downside biases. Pure risk is divided into two further sub-categories:

[13] Weitzman (2007) includes risk premiums in the social time preference formulation for the uncertainty relating to the parameters within the formulation.

- idiosyncratic risk, which is random variation
- systematic risk, which is variation correlated with the level of general economic activity.

A representation of these components is contained in figure 6.1.

Figure 6.1 Risk taxonomy, following the definitions by the BTRE



The BTRE (2005) argues that adding a risk premium to the discount rate is highly unsatisfactory as it arbitrarily penalises projects' benefits heavily but does not penalise the costs, although, in many cases, it is the costs that make up the greatest portion of risk.

6.2.2 Effect of risk premiums on analysis

The BTRE (1999) provides examples of the limitations and distortions caused by managing risk via the discount rate only. One of these is a project in which construction cost is the only risky outcome. Increasing the discount rate for this project would have marked down benefits after construction as a result of risks arising during construction. In this instance, the benefits are certain, so their present value, discounted at a 'riskless' rate of interest, properly measures them.

The BTRE's argument is adding a risk premium to the discount rate does not differentiate between road projects with varying levels of risk. But it does affect the BCR ranking of projects in totally arbitrary ways that have nothing to do with risk. The BTRE argues that CBA should allow for risk, but not through the discount rate.

6.2.3 Downside risk

A good deal of evidence suggests that *ex ante* evaluations of investment projects tend to be over-optimistic when compared with *ex post* performance (Department for Transport UK (DfT) 2004). The difference between a projection biased towards the optimistic side and the expected value can be termed 'downside risk'.

Adding a risk premium to the discount rate is a rather arbitrary way to correct for downside risk. It engenders little or no increase in construction costs, and reduces benefits at an increasing rate over time. It would be pure coincidence if the pattern of reductions in benefits arising from a risk premium corresponded with the adjustments necessary to remove downside risk.

Approaches to dealing with downside risk are discussed in section 6.2.7.

6.2.4 Idiosyncratic risk

As long as the benefits of individual projects are spread widely over large numbers of individuals and numerous projects are in operation, idiosyncratic risk should be largely diversified away. This is a widely accepted conclusion of Arrow and Lind (1970). In the CAPM approach, idiosyncratic risk is assumed away by virtue of a sufficiently diverse portfolio.

6.2.5 Systematic risk

A welfare economist might define the systematic component of risk for public sector projects as the risk that arises from project benefits being correlated with benefits from other projects or with movements in *the economy as a whole*. A financial economist may define it as risk that arises from project benefits being correlated with movements in *equity markets*. This distinction is discussed in Spackman (2006). Volatility of the economy as a whole (as measured by aggregate consumption) is very much lower than the return from private equity markets. As a result of the markedly lower volatility against aggregate consumption, the risk premium is dramatically lower than that of the equity markets.

In fact, accounting for the difference between the two approaches has led to an ongoing field of research described as the equity risk premium puzzle, which will not be covered in this report.

Using a welfare economics approach, Spackman (2002) calculated a risk premium in the order of 0.15%; the BTRE (2005) calculated it to be in the order of 0.1%. The BTRE then argued that this is trivial enough to fit in the margin of error of CBA and thus can be ignored: a project with a BCR of over 1.001 would still have a BCR of over 1 with the risk adjustment in the discount rate.

Spackman (2002) argues that the STPR should not include a risk premium based on the market risk premium, as this is not a net social benefit but is compensation to financiers for, in particular, equity market variability.

The BTRE (2005), however, notes that in particular circumstances, pure risk (idiosyncratic risk and systematic risk) cannot be ignored, and this is when a project has a large effect on the welfare of a small number of individuals. They provide a framework for analysing such situations that does not require adjustments to the discount rate.

6.2.6 Other arguments for and against a risk premium in the discount rate

The BTRE (1999) provides additional arguments for excluding risk from the discount rate. Discount rates with risk premiums are so entrenched in CBA tradition that they may strike the unwary as a first best solution; they are not. To deal with risk through the discount rate can also invite other ‘misuses’ of discount rates, such as advocating for a lower discount rate as a catch-all allowance for things too hard to value, which would be entirely arbitrary.

6.2.7 Alternative approaches to managing project risk

Downside risk is part of a wider problem called 'optimism bias' (DfT 2004; Foster 2007; Treasury UK 2006). Besides the simple failure to consider what can go wrong, some political-institutional factors give project proponents incentives to overstate the positives and understate the negatives.

The BTRE (1999 and 2005) argues that, given that pure risk, can be ignored in most practical situations, the need to minimise downside risk still remains and the way to do so is via the 'state-contingent' approach. It involves identifying alternative 'states of nature' in which levels of costs and benefits may be different, assigning probabilities to those states of nature and estimating expected values for the various CBA results. The United Kingdom Treasury (2005) supports this approach and discusses the formation of a 'risk register' to identify risks, and the results of an appraiser's analysis and evaluation. Using the state-contingent approach encourages the analyst to consider what can go wrong in detail and to assess the effects for CBA. A Monte Carlo analysis can then be undertaken for more complex projects – the process that the NZTA requires for large projects.

To redress the tendency of optimism bias, the United Kingdom Treasury (2005) advocates that appraisers should make explicit, empirical adjustments to the estimates of a project's costs, benefits and duration. In the United Kingdom, the default uplift factors for optimism bias (for project costs) have been determined and implemented, or departments or agencies can use their own based on empirical evidence.

6.2.8 Summary and comment regarding inclusion of risk premium

Bottom-up calculations of the SOC rate are usually substantially greater than the STPR because of the inclusion of some factor of the 'market risk premium' that takes account of risk that cannot be avoided by diversification.

The arguments outlined above provide alternative ways to conceive of and measure such risk, and this risk is small enough to be ignored in the context of transport CBAs. These arguments outline important issues about the social impacts of public and private investment and, by implication, such a large risk premium does not need to be included in the social discount rate because of issues relating to risk alone.

While compelling, these arguments are not sufficient to counter the claim that the forgone private sector opportunity at the margin, represented by the SOC rate, earns a return that is substantially greater than the STPR. As Baumol (1968) said:

> *It is irrelevant to argue that the high returns in the private sector are produced by artificial distortions – taxes, risks which for society do not exist, etc. The fact that the source of this rate of return is 'artificial' makes the resulting yield figure no less substantive.*

Whether the level of social risk from undertaking most initiatives is discernable (or not) is not the primary issue that should govern policy decisions about basing the public sector discount rate on either the STPR or the SOC.

However, if discernable levels of social risk from undertaking most initiatives do not exist, this has particularly problematic implications for the CAPM/WACC specification of the SOC rate. After all, this specification is wholly reliant on the value of the asset beta – the measure of risk to assets relative to the market as a whole. Baumol (1968) notes that 'paradoxically, the very absence of real risk means that the private risk discount should also enter the social discount rate', as it 'is virtually certain from the viewpoint of society'. So if no social risk is incurred from even the highest returning portfolio, then on what meaningful basis can this parameter be set? Any value is arguably appropriate, including the highest possible value, leading to any range of discount rates being able to be specified.

6.3 Will a low discount rate crowd out private investment?

6.3.1 Key concerns

The primary policy problem is how to balance the effect on society appropriately in the short, medium and long term while ensuring that public initiatives are at least as good as the private initiatives forgone. The literature on the public sector discount rate generally strives to achieve both objectives via the choice of the public sector discount rate. The very notion that one single economic parameter can broadly solve this policy problem is probably the single key reason why economists hold such a diverse range of views as to what the public sector discount rate should be.

This section reviews how the choice of discount rate relates to the need to ensure that public initiatives are at least as good as the private initiatives forgone. This section is structured around the following three concerns:

- the use of an STPR that is less than the SOC
- the use of an STPR that is less than the long-term market interest rate
- the use of a long-term market interest rate that is less than the SOC (that is, exclusion of the market risk premium).

6.3.2 The use of an STPR that is less than the SOC

Castalia (2006a) advocates for an STPR to be used, but for it to be raised closer to the pre-tax WACC used by the private sector to an extent that becomes greater as the distortion from differing discount rates in the public and private sectors becomes more serious. The thinking here is not that the resources forgone pertain to a mixture of consumption and investment; it is to ‘maintain a level playing field across the boundary and reduce any tendency for the public sector to encroach on a role better performed by the private sector’.

Portney and Weyant (1999) describe a consensus reached in 1982 by Lind. Lind proposed three important themes that had emerged from the discounting debate:

- To the extent possible, all future benefits and costs should be converted to equivalent changes in consumption for the individuals who will experience them.
- To the extent that the costs (benefits) of a public investment or regulatory programme displace (augment) private capital formation, their consumption-equivalent measure should be adjusted upward to reflect the marginal productivity of capital.
- These adjusted streams of consumption equivalents should be discounted using the STPR.

This method requires one to determine the shadow price (resource cost) of capital. Pearce and Ulph (1999) use the rationale of Spackman (1991) to explain why the shadow pricing approach is not used in the United Kingdom. Spackman acknowledges that the shadow pricing procedure is the theoretically correct one. He also agrees that public investment displaces both investment and consumption, so that it is not legitimate to argue for an opportunity cost rate alone. Spackman's gives three reasons for not pursuing the shadow pricing approach:

> *...the problems of quantifying in practice how much a particular public expenditure is financed by diversion from investment and how much directly from consumption are formidable.*[14]
>
> [Shadow pricing] *would be quite foreign, and not attractive, to most practical managers.*
>
> *It appears in practice that, even where time preference and the opportunity cost of displaced investment might in principle conflict, this conflict, at lease* [sic] *in present UK circumstances is not generally material.*

In short, the justification for not going down this route is a mix of practicality and the belief that the STPR and the SOC are in fact very close to each other.

Young (2002) does not comment much on the possible concerns of using a STPR that is lower than the SOC rate, except that any project that has a positive NPV with the higher discount rate will also have one with the lower discount rate. Interestingly, the BTRE (1999 and 2005) notes that this might not be true for the evaluation of nuclear power plants that have a high decommissioning cost (see Pearce et al 2003 for a case study on this issue). Young argues that this is satisfactory for clear-cut results, but could lead to under-investment if NPV results close to zero are not investigated further.

Rose (2006) advocates for the STPR but acknowledges that:

> *...doubts remain, particularly when one considers the range of projects that potentially lie alongside or across the public private boundary. Roads, hospitals, prisons all fall in this category and raise the question of why we should adopt different assessment rules on either side of this frontier.*

Rose's view is that the responsibility for ensuring that public spending is well balanced and is focused on areas of primary need lies with the budgetary process as a whole rather than being encapsulated in one single parameter. This is a view supported by the New Zealand Treasury (2005): the appropriateness of government intervention is a key factor to consider[15].

Rose (2006) also notes that in New Zealand, we have resolved the dilemma of trading off the STPR with the SOC by simply using the latter concept. But this imposes a discount rate on us that heavily penalises long-term projects.

Castalia (2006a and 2006b) also notes that the concerns of the 1970s – that government activity crowded out either private investment or consumption – were based on closed economy models. With international finance being available, the act of government investing in a project is far less likely to crowd out private sector involvement at the macroeconomic level, undermining the justification for using the SOC rate.

Feldstein (1972) defended the STPR against claims it should not be used if it is lower than the SOC:

---

[14] In other words, a share estimate is required for each individual project.

[15] The Treasury (2005) describes the following further considerations additional to CBA: appropriateness of government intervention, the attractiveness of competing proposals/uses of funding, strategic value, affordability, the importance of possible intangible costs/benefits, and any implementation difficulties.

> *Several economists have advocated disregarding time preference completely and defining the discount rate [i] as the rate of return on private investment. They argue as follows: since the resources used in any public expenditure project could have been invested in the private sector where they could have earned a yield of* i*, public projects should not be undertaken unless they will obtain an equal yield. This argument reflects a basic ambiguity in the notion of opportunity cost. Economic textbooks often define opportunity cost as the value of resources in the best alternative use to which these resources* ***could*** *be put. This definition is implicit in the argument above. In fact, the actual opportunity cost of any resources is their value in the alternative use to which they* ***would*** *have been put. The two coincide in a perfectly functioning economy: if resources are not used in one activity they* ***would*** *be used in the most valuable alternative to which they* ***could*** *be used. But it is the very essence of the second-best problem that resources that could be invested with greater value are instead consumed. The economists who advocate discounting by the return on private investment fail to distinguish between the 'ideal opportunity cost' (what could be done with the resources) and the predictive opportunity (what would be done with them).*

One might say that because legislation precludes the NZTA from investing in the sharemarket, the funds invested by the NZTA could or would not possibly otherwise be invested in the sharemarket and earn the SOC rate. However, more broadly, this is not a sufficient counter-argument against the need to consider the forgone private initiative. Over a longer period of time, the government could allocate its funds to different sectors, or even reduce taxation and total government spending; the performance of the NZTA's investments, as measured by CBA, could influence this.

The main question on which approach to use is whether, or how much, government expenditure displaces private investment. This is not straightforward under the assumption of efficient capital markets which would tend to see capital flowing to all opportunities that had positive NPVs. A broad issue is the extent to which the funds raised suppress the occurrence of positive NPVs of private investment opportunities by way of corporate taxation and other additional expenses.

Given that the National Land Transport Fund (NLTF) is now essentially funded from hypothecated transport revenues (fuel excise duty, road user charges, and motor vehicle registration and licensing fees[16]) rather than corporate taxation, the raising of revenues is probably more likely to displace private consumption than private investment. The road user charges etc incurred by firms using the transport network arguably increase costs and may potentially lead to less private sector initiatives being undertaken, but this is probably immaterial and would probably fall within the margin of error of CBA. The extent to which these specific forms of revenue displace consumption rather than investment is an empirical matter, and no research on this has been undertaken to our knowledge. Szeto (2002) estimated the marginal propensity to consume in 1987–2001 as being 0.98, meaning that a dollar less income leads to 98 cents less consumption, but found this estimate is sensitive to the estimation period. The displacement of private consumption rather than private investment would imply that the use of an STPR is appropriate and concerns about the SOC could be ignored in this specific context.

[16] This is a result of the Land Transport Management Amendment Act 2008 (New Zealand Government 2008). The National Land Transport Programme 2009–2012 has 98% of the NLTF being funded from these hypothecated revenues.

6.3.3 The use of an STPR that is less than the long-term market interest rate

Marglin (1963) made the following argument:

> *...market-determined rates of investment and interest, even rates determined in a competitive market, need have no normative significance, and that the optimal level of investment for an economy is the level at which the marginal productivity of investment equals the marginal* social *rate of discount incorporating external effects, rather than the level at which the marginal productivity equals the market rate of discount determined by unilateral investment and saving decisions... [if] the marginal social rate of discount is lower than the market rate, then the impact of this result in a frictionless competitive model is that the community in its collective, political capacity properly sees to it – directly or indirectly – that investment opportunities with future returns too low to justify private exploitation without the intervention of the state are in fact undertaken.*

To mitigate the excess public investment that would result from a discount rate being lower than the market rate, Marglin (1963) considers the displacement of private sector investment. He determined a opportunity cost parameter based on the shadow price to scale up the value of public sector capital investment to dampen demand based on multiple assumptions about:

- the private sector's marginal propensity to invest
- marginal propensity to consume
- the marginal propensities for all subsequent benefit streams in perpetuity.

However, Castalia (2006a) argues that this framework is based on a model of the economy that is not fully open to international markets. Based on Lind (1990), Castalia notes that in a world of integrated capital markets with free capital mobility, the strong link between total domestic savings and total domestic investment is broken, and the displacement of private sector investment by the public sector is no longer of concern.

Arrow (1995) says that even if a normative STPR was accepted, the opportunity cost argument would still be valid. Arrow advocates for the rate of discount to be some balance between the STPR, governed by altruism, with the rate of return on private capital. Arrow (1995) also argues that an STPR should not imply a savings rate that is higher than what is credible. If it is more than would be credible, then we can conclude that the proposed discount rate is too low.

Spackman (2004) states that national welfare will be lost if an investment is undertaken only because of the use of an STPR that is less than the expected post-tax rate of interest on government debt. If the STPR was lower than this rate, a strong case could be made for using the post-tax borrowing rate as a public sector discount rate. Spackman noted the possibility of the post-tax cost of UK government borrowing occasionally exceeding its current 3.5% real discount rate, but states that it is unlikely that real interest rates in any OECD country would ever be expected to exceed the government's chosen STPR consistently.

The OECD (2007) says that while the focus ought to be on determining the STPR (using proxies or otherwise), this does not mean that market interest rates are irrelevant. If public investment crowds out private investment, the opportunity cost of that investment is the market interest rate. The impact of public spending crowding out private spending should be addressed, probably by converting any consequences into their consumption equivalents through the use of a shadow price on capital (this is the approach advocated by Lind (1982) described previously).

Oxera (2002) simply says that in regard to the allocation of resources (wealth) over time within a generation, the issue is addressed by adopting a social discount rate with the usual adjustments for market distortions.

While compelling ethical arguments suggest why the social discount rate might be lower than (long-term) market interest rates, some pragmatic issues might invite caution about their plausibility. If the STPR was significantly lower than the government's cost of debt, say in the international market, the government could undertake NPV positive projects that may fail to cover the international cost to the country of the interest payments, particularly if the benefit streams are intrinsic benefits only.

While such a project could not cover its own financial costs without additional support, this does not necessarily mean it is not socially optimal, particularly if no increased chance of defaulting on the loan is possible. This is particularly the case if all initiatives partly or fully funded from the NLTF are funded from transport revenues and only relatively modest amounts of debt were incurred. Provided that any NLTF debt levels remain modest, and that hypothecation of transport revenues continues, using the STPR will probably not have any adverse effect on debt for such investments even if the STPR is below the long-term market interest rate.

6.3.4 The use of a long-term market interest rate that is less than the SOC

The BTRE (1999 and 2005) highlights the theoretical complexities with the proper use of shadow pricing and choosing an alternative numeraire (the unit of accounting in an economic framework). They conclude that in the absence of a better solution, the government bond rate is the most appropriate discount rate to use (BTRE 2005). This logic is not dissimilar to that presented previously by Spackman (1991) and Pearce and Ulph (1999), except that the conclusion is perhaps pragmatic and transparent as opposed to constructing an STPR from a range of disputable parameters at the risk of spurious accuracy.

The BTRE (2005) recognises that the evaluation of public sector projects at a risk-free discount rate that is significantly lower than rates used by the private sector for financial analysis could raise concerns about government investment crowding out private sector investment. They argue the following points:

- Addressing downside risk for public sector projects should have an offsetting effect on the lower discount rate.
- The risks and costs for the same project are likely to be different depending on whether the project is undertaken by the public or the private sector. The two sectors have different relative advantages and disadvantages, and the cost of capital is by no means the only factor that determines the net worth of a project.
- Overall levels of government investment are regulated by budgetary and political processes, not just the level of demand for public expenditure that could be influenced by the discount rate.

6.3.5 Assessing the issues of 'crowding out'

Concerns regarding crowding out need not dominate the choice of public sector discount rate. Crowding out issues are dependent on the context at hand, and can be better managed without resorting to increasing the discount rate.

- The general misconception that CBA primarily justifies government investment may be widely held. Instead, CBA simply assesses the socially optimality of initiatives irrespective of who undertakes them[17]. The primary determiner of whether the government becomes involved in areas that overlap with the private sector is whether market failure is likely or has already occurred. Government investment decisions are secondary to determining this, and must be appraised against other actions such as regulation, subsidies, duties or a laissez-faire approach.
- If the STPR was significantly lower than long-term market interest rates (eg 3% v 4%), this would constitute a significant social failure. It is not clear that the second-best solution is to simply raise the public sector discount rate.
- The primary reason why lower yielding investments may be undertaken by public agencies is if the appraisers and investors who operate in a narrow domain of activity were excessively well resourced and if they failed to consider higher yielding investments outside of their operations or mandate. This would occur if investment resources were distributed inappropriately across social activity classes. Social optimality could be obtained by allocating resources such that the cut-off BCR was the same in all sectors.

The NZTA is an entity that has the resources to evaluate and fund activities within a prescribed domain. If any major concerns regarding the social optimality of the NZTA's investments with a use of an STPR arose, then these could be offset by reviewing the domain of its operations, the level of its resourcing and the quality of its evaluations. The same would need to be done within all such sector agencies. Optimality would not be ensured by arbitrarily altering the discount rate.

Table 6.1 summarises our assessment of the key issues.

Table 6.1 Summary of crowding-out assessment

Type of concern	**Area of concern**	**Assessment**
Macroeconomic	Effect of government activity on capital markets	This is not a concern to New Zealand, which has been an open economy with significant international trade and free capital mobility for a long time. Transport revenues are mainly sourced from fuel excise duty, road user charges, and motor vehicle registration and licensing fees rather than from corporate or general taxation. These revenues most probably displace consumption, and any private investment displaced is probably immaterial.
Microeconomic	Domain of government involvement	Judgement of extent of market failure and whether activities are public goods. Independent of discount rate.
	Operational activities	Many factors should be considered. The discount rate is minor relative to these: • capital resourcing • extent of government subsidies • other policy and evaluation frameworks • general governance structures and operating parameters • discount rate.

[17] If the choice of provider matters then these scenarios can be modelled also.

Regarding the concerns about the government operating in areas better served by the private sector, we would not advise altering the discount rate in the first instance – at least not for the primary role of a social CBA of evaluating the social returns of initiatives. Additional budgetary and political processes and judgements, in part overseen by Treasury, should be relied on. The public sector discount rate should not be used as a proxy for solving poor government decisions.

7 International practice

Rose (2006) reviewed the international practice for discounting and made the following observations:

- Internationally, thinking has significantly shifted away from use of private sector opportunity costs as the normal reference point.
- The justification for this shift is based on the likely pattern of, and tolerance to, risks in public sector projects. Systematic risks associated with likely benefit flows are argued to be typically small when evaluated against aggregate consumption. The quantitatively most important class of risks is downside risk, and this is more appropriately dealt with by probabilistic assessment of outcomes rather than by adding an element within the public sector discount rate.
- In certain instances where the private sector rates of return remain in use, reference rates have either been lowered or made indeterminate, and the use of long-term bond rates is permitted in some circumstances.

Table 7.1 summarises current practices overseas, and is based on research by the OECD (2007) and a range of other sources including Spackman (2006), the Ministry of Economic Development (MED) (2007) and others. The OECD report advocates the following:

- Social discount rates should be estimated according to the STPR.
- Risk-free market interest rates might serve as a rough proxy, although it is preferable to estimate the STPR from first principles, according to $r = L + \delta + \mu g$.
- The social discount rate should explicitly account for uncertainty in future macroeconomic conditions (as distinct from project-level uncertainty).
- In practice, the appropriate discounting schedule for most, if not all, OECD countries will involve a discount rate that eventually declines with time.

Table 7.1 Information obtained on current practice

Country*	Summary of guidance on discounting	Approach to risk	Source
Australia	Different funding jurisdictions nominate different discount rates and vary by project type and expected risk. • Victoria uses 6.5% • New South Wales uses 7%, with sensitivity tests at 4% and 10% • Queensland has no defined value, but indications are it is generally 6%. The Australian Government Productivity Commission will release a study recommending appropriate discount rates, due for release in December 2009[18].	Infrastructure Australia advises that financial discount rates should be used for public-private partnership assessments (which are not economic cost-benefit appraisals).	Australian Transport Council (2006) Department of Transport (2008) NSW Treasury (2007) Queensland Government, Department of Infrastructure and Planning (2008)
Austria	No standardised discount rate		OECD (2007)
Canada	TBS: 8% (sensitivity at 3% and 10%) Environment Canada: 7% (5% and 9%)		OECD (2007) Moore et al (2008)
Czech Republic	Ministry of Environment: 1% (real, risk-free government borrowing rate)		OECD (2007)
Denmark	3% discount rate (STPR), but Ministry of Finance employs 6%		OECD (2007)
European Commission	4% based on gilt yields and London Interbank Offered Rates, but 'reflects social time preference'	Riskless discount rate	OECD (2007)
Finland	Discounting not widely used Ministry of Transport and Communications: 5%		OECD (2007)
France	4% for *t* <30 years, 2% for *t*>30 years since Jan 05 (reviewed on five-year cycle) 0% for certain investments.	Riskless discount rate	OECD (2007) MED (2007) Spackman (2006)
Germany	3%, approximated from long-term bond rate	Riskless discount rate	MED (2007)
Hungary	Depends upon the shape of the Hungarian forint and Euro zero coupon yield curves		OECD (2007)
Ireland	5% for all public projects, as set by Department of Finance Reviewed regularly.		OECD (2007)
Luxembourg	CBA is not employed by the Ministry of Environment		OECD (2007)
New Zealand	Treasury guidance is 6–8% depending on risk profile. Sector-specific discount rates are permitted. Energy Data and Analysis Coordination (an MED-led whole-of-government group) advises that government costs and benefits use 5% real, with sensitivities at 2.5% and 10%.	The Treasury default guidance is CAPM. It is unclear what the Energy Data and Analysis Coordination values are based on.	Treasury (2008) NZTA's EEM MED (2008)

[18] See Australian Government Productivity Commission (2009).

Table 7.1 (cont.) Information obtained on current practice

Country*	Summary of guidance on discounting	Approach to risk	Source
Slovak Republic	5% discount rate based on European Union guidance		OECD (2007)
Spain	5% discount rate, except for water infrastructure (4%), based on European Union guidance		OECD (2007)
Sweden	4% discount rate, to be reviewed in May 2006		OECD (2007)
Switzerland	No standardised discount rate.		OECD (2007)
Turkey	The discount rate is the interest rate on debt finance for the specific project		OECD (2007)
United Kingdom	3.5% rate (STPR) for first 30 years, then declining schedule	Riskless discount rate	Treasury UK (2006)
United States	3.0% or 7.0% depending upon type of cash flow, lower rates for longer-term.	Riskless discount rate	OECD (2007)

*The following countries did not tender a response to the OECD: Belgium, Greece, Iceland, Italy, Japan, South Korea, Mexico, the Netherlands, Norway, Poland and Portugal (OECD 2007).

8 Discount rates in the very long term

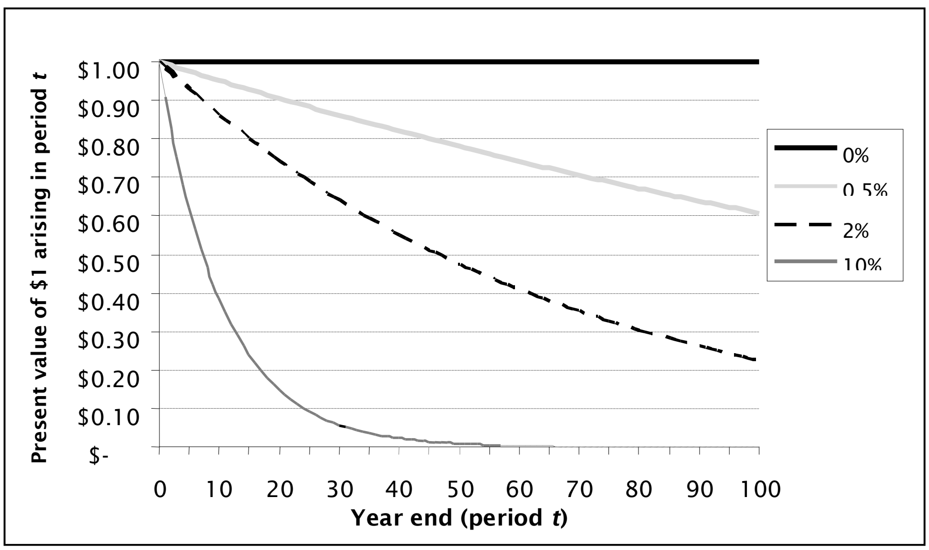
8.1 Very long-term effects

An increased level of research has been done into the value of the discount rate used when evaluating effects that will be felt between half a century and several centuries in the future. Portney and Weyant (1999) describe how renewed interest was sparked following the 1995 publication of a report led by Kenneth Arrow for the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change 1996).

Researchers acknowledge the overwhelming effect of the discount rate on the results of cost-benefit evaluations of climate change policies. Weitzman (2007) argues that the conclusions of the *Stern review* (Stern et al 2007) come from choosing a very low discount rate of about 1.5%.

The dramatic impact of discounting over the long term is shown in figure 8.1. One dollar of benefit in 100 years time is valued as being worth $0.00, $0.02, $0.23, $0.61 and $1 now at discount rates of 10%, 4%, 2%, 0.5% and 0% respectively.

Figure 8.1 Effects of compounding discount rates over 100 years



Given the effect of high discount rates when evaluating in the long term, two recent developments have occurred. The first has been discussed in chapter 7, where the trend has been toward the STPR rather than the SOC rate.

The second is that declining discount rate schedules now have a range of theoretical bases, and that these are progressively being implemented internationally and advocated for by the OECD (OECD 2007). The three schools of thought are (Oxera 2002[19]):

[19] The Oxera report (2002) played a key role in the United Kingdom's decision to adopt declining discount rates.

- **Empirical observations of how people actually discount the future.** Some evidence seems to indicate that individuals' time preference rates are not constant over time, but decrease with time. While some evidence still supports time-constant discount rates, the balance of the empirical literature suggests that discount rates decline in a hyperbolic fashion over time.
- **Time-varying discount rates derived from uncertainty about economic magnitudes**
  - When it is uncertain what the social discount rate will be, then under certain conditions, the long-term discount rate will equate to the lowest value that has a non-zero probability of occurring.
  - When future consumption levels are uncertain, then under certain assumptions, this form of uncertainty also produces a discount rate that declines over time.
- **Concerns that constant-rate discounting shifts unfair burdens of social cost on to future generations.** It adopts specific assumptions (axioms) about what a reasonable and fair balance of interests would be between current and future generations, and then shows that this balance can be brought about by a discount rate that declines over time.

One key concern for theorists regarding declining discount rates: it may lead to policies that are inconsistent over time. That is, a policy may be undertaken that is in the policy maker's best interests initially but later becomes sub-optimal for no other reason than the mere passage of time. Newell and Pizer (2000), however, argue that this is an issue relating to a deterministic declining discount rate only, and that a declining certainty-equivalent rate 'fits squarely within the standard framework of geometric discounting based on market-revealed rates.'

8.2 Materiality of declining rates for the New Zealand land transport sector

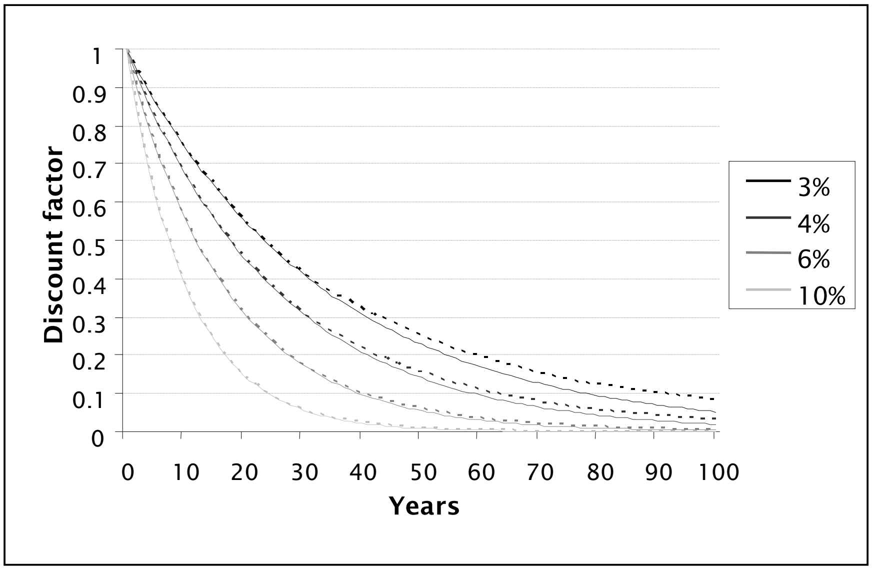
Table 8.1 summarises the schedule of social discount rates employed in the United Kingdom, starting with a value of 3.5%.

Table 8.1 Example of typical declining discount rate schedule

Time period (y)	Discount rate reductions from default discount rate
0–30	No change
31–75	0.5% reduction
76–125	1% reduction
126–200	1.5% reduction
201–300	2% reduction
301+	2.5% reduction

To provide a sense of the full effect of declining discount rates, figure 8.2 applies this schedule using a variety of initial values for the discount rate (the dotted lines representing the declining discount rates).

Figure 8.2 Impact of declining discount rates compared to non-declining rates



Two observations can be made from this:

- Over a 100-year period, the effect of such a change is modest.
- A lower initial value has a greater impact. At the highest value of 10%, very little left is to discount after 30 years, and so marginally lowering the discount rate will have no significant effect.

A preliminary conclusion is that the issue of declining discount rates seems to be less applicable to land transport investments and more applicable to policies and initiatives that have very long term effects, such as climate change policy evaluations. Therefore, this review will provide only a limited coverage of the literature – for further reading, we recommend three key readings: Oxera (2002), Pearce et al (2003) and OECD (2007).

8.3 Key reasons for using a declining discount rate

The OECD (2007) argues that the most compelling reason for a declining discount rate is based on the work of Weitzman (1999, 2001, 2007). When it is uncertain as to what the social discount rate will be, then under particular conditions, the certainty-equivalent marginal (instantaneous or year-specific) discount rate tends towards the lowest discount rate that could be possible as the analysis period extends.

This is based on an analysis of *discount factors* rather than discount rates, where the discount factor d is defined as shown in equation 8.1.

$$d_t = \frac{1}{(1+r)^t} \qquad \text{(Equation 8.1)}$$

where:

r = the discount rate.

The marginal discount rate at time t is given by equation 8.2:

$$r_t = -\frac{d_t - d_{t-1}}{d_t} \qquad \text{(Equation 8.2)}$$

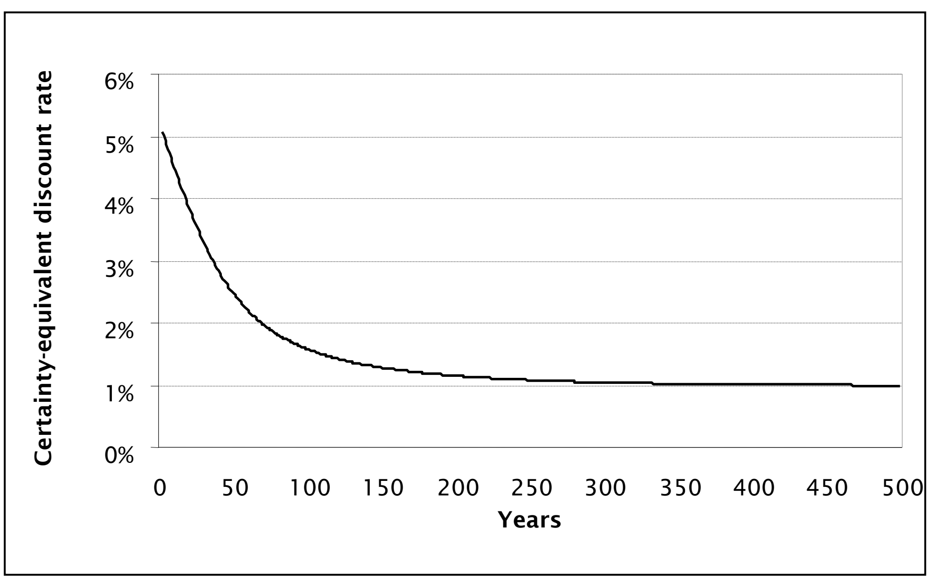
When it is uncertain as to which discount factor to use, the variable over which we should take expectations is not the discount rate *r*, as is typically done, but rather the discount factor *d*, which enters expectations linearly (Newell and Pizer 2000). Table 8.2 below demonstrates the effect of uncertainty over a range of possible steady discount rates between 1% and 10%, and how the certainty equivalent discount rate declines from 5.14% to the lowest value (1%) over a long enough period.

Table 8.2 Example of declining discount rates when discount rates are uncertain

Equally possible social discount rates	Discount factors in year:					
	1	10	50	100	200	500
1%	0.990	0.905	0.608	0.370	0.137	0.007
2%	0.980	0.820	0.372	0.138	0.019	0.000
3%	0.971	0.744	0.228	0.052	0.003	0.000
4%	0.962	0.676	0.141	0.020	0.000	0.000
5%	0.952	0.614	0.087	0.008	0.000	0.000
6%	0.943	0.558	0.054	0.003	0.000	0.000
7%	0.935	0.508	0.034	0.001	0.000	0.000
8%	0.926	0.463	0.021	0.000	0.000	0.000
9%	0.917	0.422	0.013	0.000	0.000	0.000
10%	0.909	0.386	0.009	0.000	0.000	0.000
Certainty-equivalent discount factor	0.949	0.610	0.157	0.059	0.016	0.001
Certainty-equivalent marginal discount rate	5.14%	4.51%	2.47%	1.58%	1.15%	1.00%

Figure 8.3 further demonstrates the nature of the rate of decline of the certainty-equivalent discount rate for this example.

Figure 8.3 Example of declining certainty-equivalent marginal discount rate



The reason for this result is that, possibly, higher rates have rendered themselves insignificant through the power of compounding over time – over time, higher discount rates receive less and less weight as they are discounted away (Newell and Pizer 2000).

This result relies on persistence in the discount rates, and their not reverting to some mean value. Newell and Pizer (2000) tested this proposition and found significant empirical evidence that historical rates are indeed uncertain and persistent, which would support the employment of declining certainty-equivalent values. However, the particular path of certainty-equivalent rates crucially depends on whether one believes that interest rates are a random walk or are mean-reverting, a determination that is ambiguous in the data. Under the random walk assumption, the value of the future consequences of carbon dioxide emissions is nearly doubled, whereas the mean-reverting model leads to a modest 7% increase. Note that while Newell and Pizer find a random walk model more appealing, such a model would allow society's real discount rate to roam unbounded, which may not have wider appeal to policy makers.

8.4 Conclusions regarding long-term discounting

Theoretically, economists have a defendable basis for using a declining discount rate schedule, regardless of what paradigm is used to base the social discount rate upon (be it SOC, STPR or any other framework).

However, declining discount rates will not have strong significance for transport investment appraisals, as the analysis period is not generally long enough. On those rare occasions where the analysis period of a transport appraisal is long enough, the inherent uncertainties within the transport appraisal itself after about 30 years mean that a declining discount rate should fall well within the margin of error of the appraisal.

This study will not empirically assess the effect on the cost-benefit appraisals of transport projects using declining discount rate schedules.

9 Conclusions regarding the social discount rates

9.1 Summary of the key issues

- Two key approaches are used to determine the social discount rate applied in economic CBA: the STPR and the SOC rate. These rates cannot be reconciled in any simple way.
- The STPR represents how society values consuming now versus consuming in the future, where ‘consumption’ can be thought to encompass the general welfare of citizens. Adopting this approach is becoming much more widespread internationally. This approach leads to (real, inflation-adjusted) discount rates perhaps in the order of 3%–5%, but that range could easily be wider depending on the parameters used. Determining these parameters necessarily involves subjective and normative judgements to be used, and involves problems of uncertainty.
- The SOC rate reflects the opportunity forgone from diverting funds to a public investment. The discount rate prescribed by the Treasury is based on this paradigm, using the CAPM. It can generate real discount rates in the order of 5%–15%, depending on sharemarket and interest rate parameters, and the treatment of company tax. Including company tax lifts the SOC rate by 25%–50%. The New Zealand public sector discount rate is based on the pre-tax value. The justification for applying a higher pre-tax rate for all government CBAs when no tension exists between public and private sectors to provide a given good or service is unclear.
- CAPM specifications of the SOC rate are much larger than STPR estimates because of an allowance for risk. However, welfare economists have estimated that a social risk allowance would be less than 0.1%, which is small enough to ignore. While, perhaps, we have no compelling reason to include a significant risk allowance in the public sector discount rate, the fact remains that public investments need to demonstrate that they are at least as good as forgone private initiatives, irrespective of why the forgone private initiatives earn what they do.
- The literature often describes the SOC as being easier to estimate than the STPR. However, a CAPM specification of the SOC rate has several problems. The CAPM does not assess effects from a social perspective but from the perspective of a private investor. Share purchases may not cause additional initiatives to be undertaken, and any additional initiatives that are undertaken may not be sufficiently comparable with the initiatives being explicitly evaluated. The notion that no discernable level of social risk arises from undertaking even the highest returning portfolio means that the CAPM method could possibly specify an enormously wide range of discount rates.
- Given that the NLTF is now essentially funded from hypothecated transport revenues (fuel excise duty, road user charges, and motor vehicle registration and licensing fees) rather than corporate taxation, the raising of revenues is probably more likely to displace private consumption than displace private investment. The road user charges etc incurred by firms using the transport network arguably increase costs and may potentially lead to less private sector initiatives generally being undertaken, but this is probably immaterial and would probably fall within the margin of error of CBA. This would imply that the use of an STPR is appropriate and concerns about the SOC can be ignored in this specific context.

- Concerns about specific NLTF-funded activities crowding out specific private sector initiatives can best be managed by good governance processes and informed use of CBA by the NZTA and approved organisations rather than wholesale lifting of the discount rate.
- A theoretically plausible basis on which to enact declining discount rates over the very long term exists, but this would have only a modest effect on land transport investments given the substantial uncertainty of effects that far in the future. A reduction would probably be in the order of between 0.5% and 1%, depending on the size of the initial discount rate scenario, and would commence at about year 30.

9.2 Conclusions regarding the social discount rate

9.2.1 The appropriate choice of discount rate to use for land transport CBA

The use of an STPR is advised for the cost-benefit appraisals of initiatives partly or fully funded from the NLTF. The precise value of this has a degree of uncertainty and involves normative (rather than scientific) judgements about the value of the pure time preference rate and properties of the social welfare function now and over time.

After considering some plausible values of the relevant parameters, we believe that the appropriate value may lie between 3%–5% real, but the range may be wider than this. A mid-point value of 4% is appropriate, but the final decision should lie with policy makers rather than economists, given the normative judgements required.

It is possible to consider a declining discount rate schedule. However, it is more important to resolve issues and concerns regarding how to evaluate the long-term impacts felt in 30–80 years' time (discussed further in section 12.3.2) before considering such modest refinements to the discount rate.

9.2.2 The range of plausible discount rates

In terms of defining a range of plausible discount rates to test, we saw no plausible basis to consider a discount rate greater than 10%, and so this is the upper boundary considered. The lower bound on this range of social discount rates needs to be appropriate for the data available. Applying a discount rate that is too low compared to the 10% discount rate applied when the CBAs were developed could be too limiting. Possible technical problems largely stem from a lack of available data:

- analysis periods that are too short (ie that do not see any effects after 25 years)
- exclusion of relevant alternative projects (and alternative configurations of projects) because they were never economic contenders at a 10% discount rate.

After having reviewed the available data, we conclude that a 3% discount rate is probably the lowest that can be applied while still providing meaningful insights from the available data.

For the remainder of this report, a range of social discount rates between 3% and 10% will be applied. A declining discount rate schedule will not be considered. It is noted that 3% is not the lower bound for a theoretically plausible value of the STPR.

10 Assessing the impact of the discount rate

10.1 Objectives of assessment

This chapter outlines how the impacts of altering the discount rate are quantified.

The motivation of the research is that reducing the discount rate will potentially have a wide range of outcomes (depending on the size of the reduction):

- Many more projects will successfully meet minimum benefit-cost criteria.
- Given fixed funding budgets, fewer projects can be afforded, as projects are being built at a higher quality and greater scope because project promoters will be able to justify more features.
- As more projects become economically justifiable, more social and environmental elements can be incorporated, which may further threaten an increase in the scope, and thus the cost of projects.
- Maintenance approaches and treatments will change, eg the attractiveness of area-wide pavings.
- More excess demand for investment funds will be created, as more worthwhile projects will be identified that cannot be funded within existing budgets.
- The relative attractiveness of land transport investments, such as walking, cycling, motorways, small to medium road projects and public transport, will change.

These changes may alter the bequests to future generations and have an effect on current generations, and may change the mix of investments (for example, road v public transport) and these outcomes will have different long-term environmental and social effects.

This research project will investigate how the relative rankings of different types of projects might alter, and will assess the characteristics of those projects. This will help inform judgement about the effects of a discount rate change across a range of budget constraints scenarios. Projects that are more likely to receive funding might be more capital intensive projects whose benefits are predominantly travel-time savings or they might be public transport investments that reduce carbon dioxide (CO_2) emissions.

10.2 Effects on investment

10.2.1 Effects within the land transport sector

Altering the public sector discount rate may affect land transport investments by influencing the relative economic performance of initiatives that are competing for a share of a fixed pool of funds. The choice of discount rate may also influence the perceived overall social worth from land transport investments, and thus may influence the funding contribution from general taxation and other sources.

For land transport projects, a lower discount rate will improve the BCRs of all projects because they are generally characterised by costs occurring before benefits. However, it is the nature of how benefits and costs are incurred over time that govern the relative improvement in BCRs. If a fixed pool of funds is available, it is the relative rankings that are of importance.

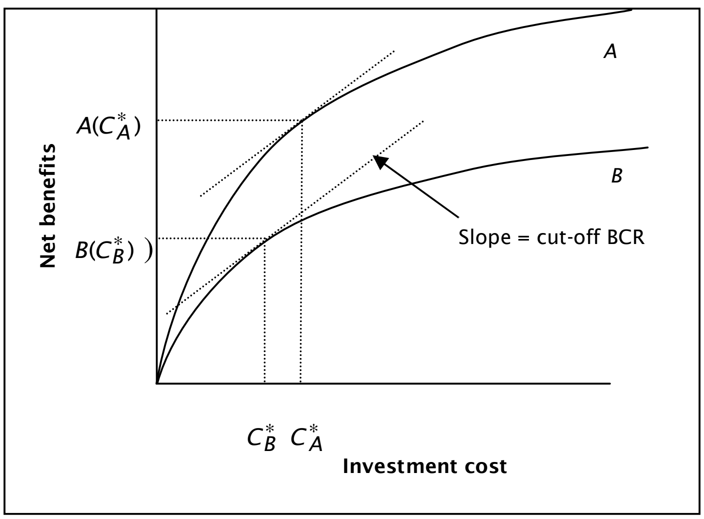
10.2.2 The stylised economic optimisation problem

The following outlines the stylised economic theory that supports the ranking of BCRs to maximise net social benefits. In practice, however, the BCRs of some types of initiatives are judged as not representing all of the value they provide, and evaluations are supplemented by non-CBA criteria.

Administrators are faced with a maximisation problem: to maximise net social benefits (the 'objective function') with the funds available in the National Land Transport Programme (NLTP). A standard economic result is that the solution to the maximisation problem in a single-period budget-constrained environment occurs when the marginal net benefits of each investment class are equal.

Figure 10.1 demonstrates an example of optimal investment levels from a single period's worth of NLTP investment. If all the potential projects in each class are ranked from highest return to lowest (ignoring projects with negative benefits) then an upward sloping concave 'production function' will be produced for each class. The optimal level of investment in class *A* activities is C_A^* and for class *B*, it is C_B^*; C_A^* and C_B^* together exhaust the budget constraint. At these levels, the marginal benefit slopes of *A* and *B* are equal and both are equal to the benefit/cost ratios (BCRs). The slope of the BCR at either C_A^* or C_B^* is called the cut-off BCR (sometimes known as the marginal BCR – discussed further in section 2.5 on page 25).

Figure 10.1 Stylised example of optimal investment in budget constrained environment



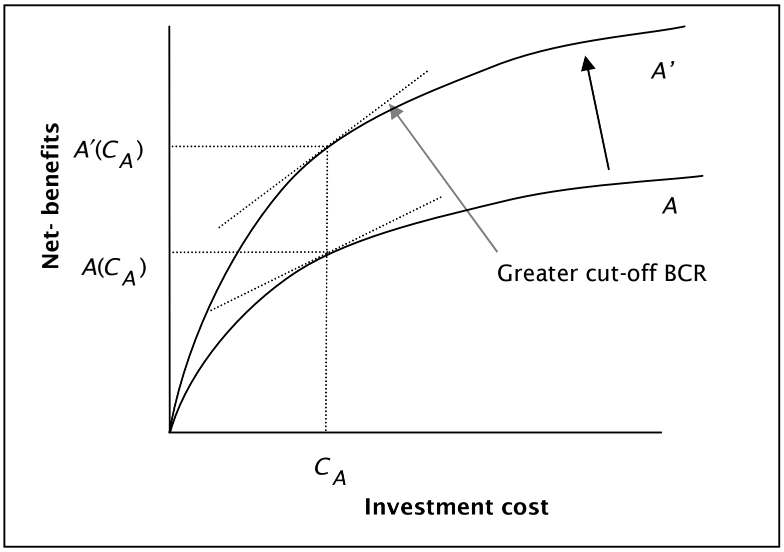
The intuition is that if activity B had less investment than C_B^*, the slope of *B* at that point would be steeper and the BCR of the marginal project in *B* would be more than *A*. Redistributing resources from *A* to *B* would improve the payoff to society as the loss of value from the withdrawn type A projects would be more than offset by the additional benefits received from type B projects.

If the size of the budget permanently increased, investment in activity classes (C_A^* and C_B^*) would both increase[20]. The shape of the production functions would determine the precise level of increase, but the slopes would be less steep and thus the cut-off BCR would be reduced.

[20] Or, more generally, they would not decrease. If investments are large relative to the budget constraint (ie they are 'lumpy' in size) then some funds may be left over. Refer to ATC (2006b) for further discussion on this.

Figure 10.2 illustrates how a reduction in the discount rate would raise the BCRs of all projects, and that this leads to a higher cut-off BCR if the budget does not expand.

Figure 10.2 Stylised example of a greater cut-off BCR when the discount rate is reduced and the budget is fixed



The key point to note is the set of projects funded under the status quo discount rate will probably not be the same as those funded if the discount rate was lowered because of the different occurrences of costs and benefits over time across all projects. It also follows that the 'marginal project', the project with the lowest BCR out of all those funded, could differ in either instance.

10.3 Method

10.3.1 General notes

The CBAs of over 150 initiatives across the domain of land transport were obtained and entered into a common spreadsheet model. The key assumptions and methods for those initiatives were consistent with those prescribed in the EEM. The key model inputs are the parameters in the EEM (such as the discount rate and values for accidents, time and CO_2) plus the key data variables in each of the evaluations. All projects apply cost values from the EEM that use a common unit and that can be changed while preserving comparability across projects.

Projects were broken down into classifications such as walking improvement projects and motorway projects, and the average BCRs for each classification were calculated across the range of discount rates considered (3–10%). The proportional increase in average BCRs for each type of project is the key measure used to determine how relative rankings may change across land transport investments.

While undertaking the research, we found that the BCRs of some projects were occasionally volatile, discontinuous and generally unintuitive. A separate review of the BCR formulation was undertaken within this study to understand the basis for such results, and to assess alternative formulations to determine if a more informative and consistent approach would be possible. This is described further in chapter 11.

10.3.2 Key assumptions and limitations

- The focus of the study is on CBA results only, namely BCRs. However, BCRs may not adequately capture wider strategic imperatives and thus are only one factor in investment decisions. An indication of higher or lower priority for a type of transport initiative does not necessarily imply that more or less of those initiatives will be undertaken.
- No parameter values prescribed in the EEM were altered. However, the basis for some unit cost values may be implicitly based on the discount rate, such as perhaps the cost of carbon, the cost of crashes, and other health and environmental concerns that do not represent immediate effects only.
- The size of the available budget for funding transport initiatives is expected to remain constant or increase only modestly as the discount rate is altered.
- CBA results for initiatives are particularly influenced by the respective base cases. If a different discount rate led to a different pattern of investment, then in the long term, the nature of the overall network may change, altering the properties of the base cases in future periods. The data this research is based on may become less representative. Thus the ability to assess in the long term, say in 25+ years, is more limited.
- The lowest discount rate considered is 3%. This is because applying a discount rate that is very low compared to the 10% discount rate used when the CBAs were developed has limitations. Possible technical problems largely stem from a lack of available data:
    - analysis periods that are too short (ie that do not contain impacts after 25 years)
    - exclusion of relevant alternative projects (and alternative configurations of projects) because they were never economic contenders at a 10% discount rate.

10.4 Data

The basis for most of the data on economic evaluations was from LTP Online, the NZTA's internet portal system for approved organisations to submit their land transport programmes. This was augmented by occasional project evaluations obtained through other day-to-day means and/or supplied direct to Hyder by the NZTA for research purposes only. Most approved organisations kindly provided read-only access to their secure portals.

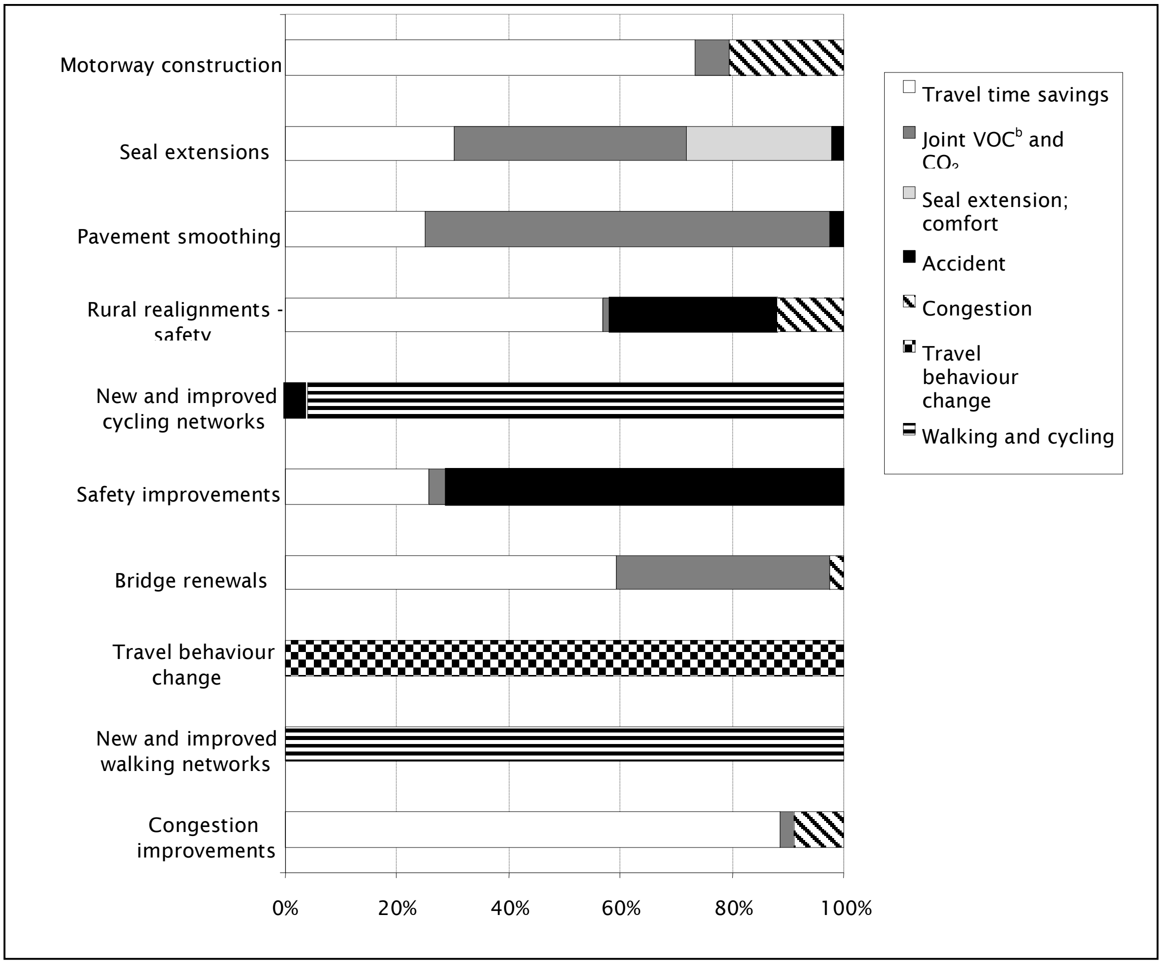
The dataset contains the time profiles of costs and benefits for about 150 projects. Table 10.1 contains an overview of the projects included in the model. The projects are representative not of the NLTP but of the projects that are included in LTP Online. Seal extensions feature so heavily because they require only simplified procedures to be used and are frequently reported by regional authorities via LTP Online.

Table 10.1 Current (2007–2009) value of projects used to generate the model

Project type	Number of projects	Average present value cost ($)
Motorway construction	2	249,500,000
Seal extensions	50	152,878
Pavement smoothing	37	209,917
Rural realignments - safety	2	2,829,000
New and improved cycling networks	10	489,300
Safety improvements	9	383,937
Bridge renewals	4	754,840
Travel behaviour change	8	338,200
Preventive maintenance	21	-49,649
New and improved walking networks	5	250,320
Congestion improvements	2	553,350

Figure 10.3 shows the relative benefit shares for each project type from the 151 projects (excluding the 21 preventive maintenance projects, which focus on cost savings only).

Figure 10.3 Types of benefits for the projects within the dataset (discounted at 10%)[a]



Notes to figure 10.3:

a Congestion benefits are as defined in the EEM.

b VOC = vehicle operating costs.

11 Review of the BCR formulation

11.1 General observations

When lowering the value of the discount rate, we expected that BCRs would steadily improve. However, it was observed that the BCRs of some projects tended very rapidly towards infinity as the discount rate was gradually lowered and then increased from negative infinity as it was continued to be lowered. Our understanding from previous projects is that the internal NZTA convention is to assign such projects a BCR of 99 and give it funding priority; the economic optimality of this was not always clear.

This observation was attributed to the specific BCR formulation used. A review of the literature identified alternative formulations of the BCR. We found that these formulations avoided these extreme effects and were potentially more informative for policy makers and investors.

This chapter outlines the findings of the review. The objectives of this chapter are to:

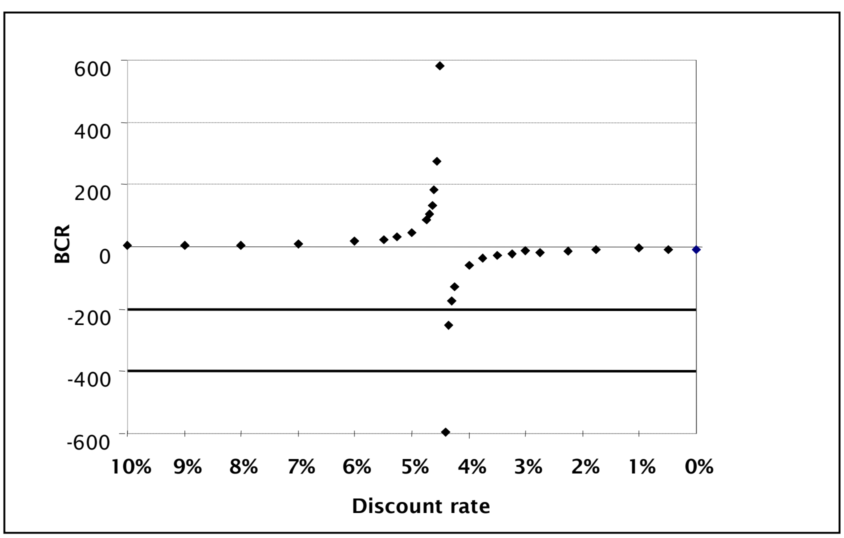
- demonstrate and explain the observed problem with some BCRs
- describe major alternative BCR formulations and their rationale
- review each formulation against three broad principles relating to materiality, net benefit maximisation, the need for CBA results to be consistent, informative and intuitive.

These aspects are followed by our conclusions and recommendations.

11.2 Example of discontinuous BCR as discount rate reduced

Figure 11.1 demonstrates how the BCR of a typical seal extension project responded as the discount rate was reduced.

Figure 11.1 Typical seal extension BCR with operating costs as the denominator



Two reasons explain this hyperbolic result:

- Costs are calculated by comparing the project option to a do-minimum base case that also involves expenditure.
- Operating and maintenance cost savings are included in the denominator of the BCR.

For many projects with a relatively strong impact on future costs, a discount rate exists where the present value cost of a project with high initial cost and low ongoing costs will equal a base case comparator that involves a low initial cost and high ongoing costs. Given that the denominator of the BCR is the difference in costs, the denominator will be zero at this discount rate. A still lower discount rate would lead to a negative BCR.

Table 11.1 provides a numerical example of a similar project where the initial cost is high but involves ongoing cost savings that lead to a near zero cost in the denominator of the BCR at a discount rate of about 4.5%, and a negative 'cost' and thus a negative BCR for discount rates below this. (The uniform annual cost savings are assumed for simplicity of presentation only.)

Table 11.1 Numerical example of seal extension cost calculations (in thousands)

Present value (PV)	Discount rate					
	10%	6%	5%	4.5%	4%	3%
$350 investment cost	$318	$330	$333	$335	$337	$340
$23 annual maintenance cost savings (years 2–25)	-$207	-$289	-$317	-$333	-$351	-$390
Total cost	$112	$42	$16	$2	-$14	-$50

11.3 Alternative BCR formulations

In the face of a budget constraint, the government objective is to maximise NPV within that constraint. The best way to achieve that is through using a BCR to rank projects, where the denominator is the present value of the costs that are subject to the budget constraint.

The main issue with defining a BCR is how to classify benefits and costs, as these definitions can materially alter the ranking of projects. The NZTA's current BCR formulation is defined below in equation 11.1.

$$\frac{\textit{Present value of benefits less disbenefits to users}}{\textit{Present value of costs less cost savings to government}} = \frac{B}{IC + OC} \qquad \text{(Equation 11.1)}$$

where:

B = present value of benefits less disbenefits to users

IC = the present value of investment costs

OC = the present value of operating and maintenance costs.

A key issue is whether the operating and maintenance costs (OC) are subject to the constraint; if they are not, then they should be on the numerator. The ATC (2006b) recommends an alternative formulation called the net benefit investment ratio (NBIR), shown in equation 11.2, which is based on Perkins (1994).

The rationale is that the NBIR, rather than the typical BCR, should be used to rank initiatives to be undertaken from the current budget because only the investment costs[21] of new initiatives are paid from the current budget, not the associated operating costs.

$$\frac{\textit{Present value of benefits less disbenefits to users, less operating costs to government}}{\textit{Present value of investment costs to government}} = \frac{B - OC}{IC} \qquad \text{(Equation 11.2)}$$

where:

B = present value of benefits less disbenefits to users

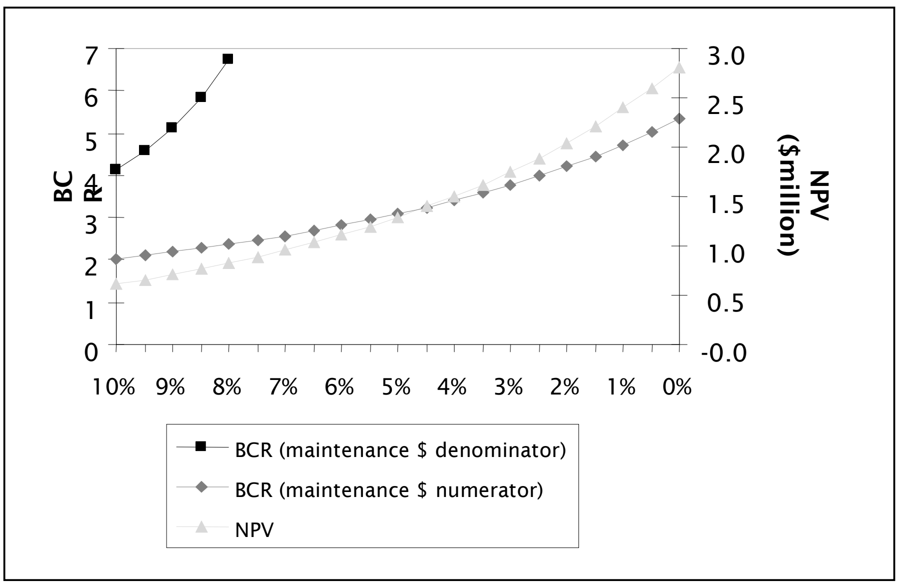
IC = the present value of investment costs

OC = the present value of operating and maintenance costs.

The ATC argues that because new capital initiatives add only a small fraction to the total maintenance costs of a road or rail network, and only well into the future when periodic maintenance is due, it is generally safe to ignore the effects of current capital initiatives on future maintenance budgets.

Figure 11.2 shows that applying this BCR formulation to the same project as figure 11.1 leads to a BCR that increases modestly and that is not too dissimilar to the increase in the project's NPV.

Figure 11.2 Comparison of existing BCR and NBIR for a typical seal extension



However, if it is necessary to assess the operating costs of current capital initiatives competing for funds with capital initiatives out of future budgets, the size of future budgets needs to be assumed, as do the benefits and costs of future initiatives. Rather than undertaking intertemporal optimisation techniques, the ATC (2006b) advises that the simplest approach to do this is to assume values for cut-off BCRs in

[21] Projects with multi-year construction periods have all investment costs on the denominator on the assumption that planning periods are longer than one year and/or that the roading agency has the ability to carry over funds to following years.

future years (cut-off BCRs are discussed in sections 2.5 and 10.2.2 of this report). Maintenance costs for all initiatives ranked in the current period could be multiplied by the cut-off BCR in the year in which they are incurred. This version is referred to here as the comprehensive NBIR, outlined in equation 11.3.

$$\frac{\textit{Present value of benefits less disbenefits to users, less operating costs to government factored by the assumed future cut-off BCR}}{\textit{Present value of investment costs to government}} = \frac{B - \mu \cdot OC}{IC} \quad \text{(Equation 11.3)}$$

where:

B = present value of benefits less disbenefits to users

IC = the present value of investment costs

OC = the present value of operating and maintenance costs

μ = the assumed future cut-off BCR, the factor by which operating and maintenance costs are multiplied to reflect the opportunity cost of funds in the future.

The review of the literature did not identify any other significantly different BCR formulations, particularly any that would affect the observed discontinuity described in section 11.2 above[22].

11.4 Review of alternative formulations

11.4.1 Three principles for evaluating alternative BCR formulations

The assessment of the alternative BCR formulations is based on the following principles:

1. The primary objective of CBA is to maximise NPV given the existence of land transport budget constraints both now and in the future.
2. As well as consistently maximising NPV from the scarce resource, the BCR should be informative for policy and decision makers, and it should allow for informative comparisons of how different types of investments perform.
3. The alternative approach would need to be substantially better than the existing approach to warrant change, in terms of meeting the above principles 1 and 2, and in terms of ease of use.

It is again noted that cost-benefit appraisals are only one component of investment decisions, and other factors can and do justify lower BCR initiatives being undertaken at the expense of higher BCR initiatives. Thus principle 1 is always likely to be traded off to some extent. As such, the review considers the ability for a BCR formulation to be consistent with the economically ideal intention of BCRs as well as the ability for a BCR formulation to contribute as much as possible to the wider decision making framework.

Table 11.2 summarises how the alternative BCR formulations perform against the principles above.

[22] The DfT (2009) is looking to refine the BCR formulation to move indirect tax impacts from the present value cost calculation and include it in the present value benefits. However, this is not of strong relevance yet to the NZTA's BCR formulation, as assessing the effects on indirect tax is not current practice.

Table 11.2 Summary of review of alternative BCR formulations

Principle	Existing BCR	NBIR	Comprehensive NBIR
1 Maximises NPV from resources that are constrained now and in the future	✔	✔✘	✔ ✔
2 Consistent and informative	✔✘	✔✘	✔ ✔
3 Alternative is materially superior	n/a	-	✔

✔ ✔ = very good performance

✔ = good performance;

\- = neutral performance

✘ = poor performance.

11.4.2 The existing BCR

11.4.2.1 Performance of existing BCR formulation against principle 1

The existing BCR formulation maximises NPV from current and future budgets when a cut-off BCR which is constant over time is consistently applied to base investment decisions upon.

The existing BCR is not able to anticipate any substantial changes in the size or demand on future budgets. If taking such a view of the future is groundless, then this is not a problem. If land transport budgets are expected to be very tight (as they might be expected to be over the course of constructing New Zealand's seven Roads of National Significance (Refer to the *NZ Government policy statement on land transport funding* (Ministry of Transport 2009)), then cut-off BCRs could be expected to be higher in those periods. This would mean that any initiatives that can be undertaken now to save or release funds in those particular periods are better. However, the existing BCR will fail to put such a premium on such effects.

A numerical example of this is provided in table 11.4 in the section reviewing the comprehensive NBIR (section 11.4.4).

Overall, with regards to principle 1, the existing BCR is rated as having a good performance. The existing BCR considers constrained budgets now and in the future. However, it cannot adapt to any expectations of future budget constraints changing in the future. This concern is only potentially important for initiatives with a significant maintenance or operating cost component, and also only if sufficiently certain expectations of future budgetary conditions can be made.

11.4.2.2 Performance of existing BCR formulation against principle 2

The existing BCR formulation implicitly factors in future budgets by virtue of future costs being included in the present value cost calculation. The implicit assumption is that the future cut-off BCR equals the value of the initiative's BCR. For instance, consider an initiative with a BCR of 2, $B/(IC + OC)=2$. Funding such an initiative is akin to assuming that it exceeds a cut-off BCR of 2 both now and in the future.

If decision makers actually expected the future cut-off BCR to differ materially from 2 (in this instance), then this BCR formulation may be misleading. However, if investment decisions are made strictly on adherence to a cut-off BCR that is constant over time, then it does not matter that decision-makers are misled in such a way, because such a project would not exceed the current cut-off anyway.

If the existing BCR is only used to go/no-go initiatives when well defined BCR cut-offs are used – and these are constant over time – then this formulation **is consistent** in that it always accepts efficient projects and always rejects inefficient projects. It **is informative** to decision makers only to the extent that they are informed that funded projects were efficient and unfunded projects were not efficient.

Because CBA is only one factor in investment decisions, it is critical that the BCRs of projects are fully comparable and their magnitudes meaningful so that initiatives can be considered against other non-CBA criteria. For BCRs to be able to do this, the CBAs must not have inconsistent assumptions about key variables. The future cut-off BCR is a key variable for projects that have a significant maintenance or operating cost component. It is more difficult to compare such projects if each makes quite distinct assumptions of future budgetary conditions. Even if forecasts of the future cut-off BCR cannot be made, it is still preferable for all such evaluations to make the same plausible assumption about the future rather than potentially very different ones.

Because the standard BCR implicitly assumes the future BCR cut-off equals itself, this overstates the initiative's impact on future budgets if the initiative's BCR is high. The standard BCR understates the effect if the initiative has a low BCR. A cost-saving project with a low BCR may appear worse than it is, whereas a cost-saving project with a high BCR has an additional advantage because of an implicit multiplier effect: the self-reinforcing impact of cost savings from the endogenous future cut-off BCR.

Consider the example in table 11.3 where two initiatives with low BCRs are considered on the basis that additional benefits to society are not captured in the BCR. The existing BCR formula prioritises initiative A over B, but if both applied a common assumption on the future cut-off BCR of 3, then the CBA would prioritise initiative B. The existing BCR formula underplays the value of initiative B releasing $2m in funds in the future, because this BCR formula implies this $2m in future cost savings corresponds to only $4m (PV) additional benefits in the future rather than the $6m in additional benefits it is expected to provide. The use of the existing BCR formulation is to implicitly assume the future cut-off is 2, contrary to the expectation that it is 3.

Table 11.3 Example comparing BCR definitions ($ millions)

Initiative	PVB[a]	PVIC[b]	PVOC[c]	BCR[d]	Comprehensive NBIR ($\mu^e = 3$)
A	10	2	2	2.5	2
B	5	4.5	-2	2	2.4

Notes to table 11.3:

a PVB = present value of net benefits

b PVIC = the present value of investment costs

c PVOC = the present value of operating and maintenance costs

d BCR = existing BCR formulation

e μ = the assumed future cut-off BCR.

The example above does not seek to suggest that initiative A should not be done; rather, it demonstrates that the additional uncaptured benefits that augment initiative A's CBA performance may need to be greater than the BCR indicates.

The CBA evaluations of projects with significant effects on costs in the future are **not consistent** because a wide range of assumptions are potentially being made on future overall budgetary conditions. This is **potentially not informative** for policy and decision makers because the magnitude of BCRs may be skewed upwards or downwards depending on whether initiatives impose further costs or save costs. *If average BCRs are much greater for one group of funded initiatives than another group of funded initiatives, one cannot necessarily conclude that they are better in CBA terms*. Projects with large investment costs relative to operating and maintenance costs are not affected by this concern.

When judged according to principle 2, the existing BCR is rated as performing well in some respects and poorly in other respects.

11.4.2.3 Performance of existing BCR formulation against principle 3

Clearly, this is not applicable to the existing BCR formulation. The existing formulation is discussed further in the context of alternative formulations.

11.4.3 The NBIR

11.4.3.1 Performance of NBIR against principle 1

The NBIR formulation performs well in that using it maximises NPV from current budgets, provided that future operating costs are negligible and/or are largely covered by future operating revenues.

However, the NBIR performs poorly in some aspects. It is not satisfactory for initiatives that involve significant future maintenance or operating costs (relative to the size of the initial investment) that are not sufficiently covered by any revenue the initiatives may generate. The use of this formulation is to assume that these costs do not come from constrained budgets (which has the same effect as assuming the future cut-off BCR equals 1). This underplays the value of cost savings and the consequences of increasing cost obligations in future. In these cases, the comprehensive NBIR is a more appropriate formulation.

11.4.3.2 Performance of NBIR against principle 2

The NBIR performs well in that it is informative because BCRs change in a continuous, progressive and intuitive fashion as lower discount rates are applied. The issue of the denominator tending towards zero for some projects, and thus extreme positive or negative BCRs at any given discount rate, is avoided as cost savings are not included in the bottom line.

On the other hand, the NBIR performs poorly in some aspects. The NBIR is not informative for projects that have a very low investment cost relative to future costs, such as subsidies for public transport services. In these cases, the comprehensive NBIR is more appropriate.

11.4.3.3 Performance of NBIR against principle 3

The NBIR is judged as having a neutral performance. The NBIR is generally good in the areas that the existing BCR is already good. It consistently maximises NPV from constrained budgets when future costs are unimportant, but so does the existing BCR. Where the existing BCR is weak, in that future significant costs are not treated consistently or in line with expectations, the NBIR also fails because it does not assume future funds are constrained. This metric is probably not materially superior to the existing BCR formula.

11.4.4 The comprehensive NBIR

11.4.4.1 Performance of comprehensive NBIR against principle 1

The comprehensive NBIR formulation is rated as having a very good performance. It maximises NPV from current and future budgets, and, if required, can anticipate any possible changes in the size or demand on future budgets over time.

Consider the numerical example in table 11.4 of a single initiative under different assumptions of the future cut-off BCR. This initiative costs $13k initially, has present value benefits of $5k, and saves $1k in operating and maintenance costs annually over years 2–25. At an 8% discount rate, under the existing BCR, the total costs (PV) are $3.25 ($13 – $5.78 – $3.97 for investment costs, operating costs years 2–10 and years 11–25 respectively), which leads to a BCR of about 1.5. If the future cut-off BCR is a constant 1.5 over time, the comprehensive NBIR also equals 1.5.

If the cut-off BCR is expected to be higher in years 2–10 (say, because of a major capital works programme such as New Zealand's seven Roads of National Significance) then the comprehensive NBIR increases the priority for this initiative, whereas the BCR is invariant to this updated expectation.

Table 11.4 Example comparing BCR definitions with different future cut-off BCRs ($ thousands)

μ[a] yrs 2–10	μ yrs 11–25	PVB[b]	PVIC[c]	PVOC[c]	BCR[e]	μ * PVOC yrs 2–10	μ * PVOC yrs 11–25	CNBIR[f]
1.5	1.5	5	13	-9.75	1.5	–$8.68	–$5.95	1.5
2	1.5	5	13	-9.75	1.5	–$11.57	–$5.95	1.7

Notes to table 11.4:

a μ = the assumed future cut-off BCR, year specific

b PVB = present value of net benefits

c PVIC = the present value of investment costs

d PVOC = the present value of operating and maintenance costs

e BCR = existing BCR formulation

f CNBIR = comprehensive NBIR.

11.4.4.2 Performance of comprehensive NBIR against principle 2

The comprehensive NBIR formulation performs very well. It allows all projects to apply **consistent** assumptions about future budgetary conditions (ie all projects can apply the same value for the future assumed cut-off BCR). Extremely positive or negative BCRs at any given discount rate are avoided because cost savings are not on the bottom line; BCRs change in a continuous and progressive fashion as lower discount rates are applied. Most importantly, it is **informative** because if the BCR of one initiative is greater than another, then one can conclude that it is better in CBA terms; this is not necessarily true of the existing BCR because of the implicit multiplier effect described above.

All project types can use this formulation, including preventative maintenance projects that only have cost impacts. Currently, these projects are automatically undertaken if they will achieve NPV cost savings (ie $IC - OC < 0$), which the comprehensive NBIR shows to always be economically efficient if the future cut-off BCR is constant over time, and users or others are not affected. (The NPV rule $IC - OC < 0$ can be rearranged to imply that $\mu * OC/IC > \mu$; ie that any cost-saving initiative can be expressed in terms of a BCR that always exceeds the cut-off threshold, provided that this threshold is constant over time.) In fact, because the comprehensive NBIR can also adapt to a changing expected cut-off BCR, it is theoretically superior to the existing NPV minimisation rule currently used by the NZTA.

Importantly, applying only one investment criterion across all land transport investments would reduce misinterpretation of the different criteria used within the sector (NPVs and BCRs). In the course of this study, we have seen some maintenance-oriented evaluations using an NPV criterion that includes benefits to users, but which makes the mistake of implicitly assuming away the existence of budget constraints. The presence of budget constraints means that costs must correspond to benefits on strictly more than a one-to-one basis, ie one dollar of cost must be worth strictly more than one dollar of benefit, which is why BCRs are used in the land transport sector. Heavily cost-oriented projects do not have intuitive BCRs, which, no doubt, contributes to why NPVs have sometimes been used in this way; the comprehensive BCR is not extremely sensitive to whole-of-life cost effects.

Finally, even projects that do not have an initial investment cost can, with a small modification, use the comprehensive NBIR by interpreting the numerator as an NPV and undertaking initiatives if it exceeds zero.

In summary, the comprehensive NBIR formulation performs very well because it imposes consistent assumptions to be made regarding future budgetary conditions, and it avoids extremely positive or negative BCRs at any given discount rate. Most importantly, all initiatives can apply this formulation and the BCRs of all of them can be fully comparable.

11.4.4.3 Performance of comprehensive NBIR against principle 3

The comprehensive NBIR performs well in that it:

- does not suffer from extreme results
- can be applied to all types of initiatives
- can adapt to changing expectations of future budgetary conditions
- allows BCRs of all projects to be fully comparable because consistent assumptions of the future are being made.

The major drawback of this approach is that the NZTA needs to make an explicit assumption of the value of the future cut-off BCR. (The basis of cut-off BCRs are discussed in sections 2.5 and 10.2.2 of this report.)

11.5 Conclusions and recommendations resulting from reviewing the BCR

If a BCR were to only do one thing, it would be to measure how good an initiative is so that decision makers can discriminate among options when budgets are scarce and can choose from the best options available. If CBA wholly governed decisions (which they do not) then cut-off BCRs would be used and it would not matter to what extent BCRs were under or over; only that they were in fact under or over would matter (similar to ordinal utility in microeconomics).

However, because other factors also influence the NZTA's investment decisions, and initiatives are traded off against multiple criteria when they are evaluated, it is the magnitude and comparability of BCRs that are of particular importance (similar to cardinal utility in microeconomics).

If the BCRs of projects with significant future cost components differ widely, then very different assumptions of future budgetary conditions are made under the existing formulation. In order to allow the BCRs of all such projects to be compared and traded off against non-CBA factors, it is important that the CBAs of each make consistent, if not the same, assumptions about future budgetary conditions, which, currently, they do not.

Therefore the concerns raised in this review about the comparability of BCRs give rise to the recommendation to **alter the BCR formula to comply with the comprehensive NBIR, which would require the NZTA to prescribe which values of the future cut-off BCR to apply.**

The main issue that would need resolving in order for the comprehensive NBIR to be used instead is how to form a reasonable assumption of the future cut-off BCR, given that no cut-off values are used now or are ever expected to be used. However, just because a cut-off BCR cannot be well defined, this is not a sufficient reason to reject this recommendation given the following:

- The government is expected to always have limited funds to invest in land transport, implying that the ratio of additional total benefits resulting from a marginal expansion to the whole land transport budget will strictly exceed 1.0.
- The current BCR formula is already using implicit assumptions of the future cut-off BCR, and these assumptions frequently vary greatly for many project types.

The assumed future cut-off BCR may not need to represent anything more than a broad and reasonable estimation of the additional social value that arises from a marginal expansion of the land transport budget (or more precisely, the ratio thereof). The use of even a rule-of-thumb value may do much to improve the comparability of BCRs across projects. However, the value needs to be well considered because it can have a large effect on the BCRs of projects with a significant future cost component, such as public transport services, seal extensions and selecting pavement types.

Ironically, it is the very lack of a cut-off BCR that requires explicit assumptions of future cut-off BCRs to be made.

12 Model results and analysis

12.1 Introduction and summary

This chapter assesses the impact of the discount rate on the BCRs of different project types. The analysis first considers the existing 25-year appraisal periods used in the existing CBAs obtained, and then considers the impact of extending this for longer-term initiatives.

Table 12.1 summarises the general properties of different investment types that generate the results.

Table 12.1 Summary of analysis results of a lower discount rate

Details	Project type			
	Motorway construction	Seal extensions	Pavement smoothing	Rural realignments – safety
Nature of benefit	Travel time savings and congestion savings	VOC* and CO_2 savings	VOC and CO_2 savings	Travel time savings, with some accident savings
Time profile of benefits	Benefit flows delayed because of construction Benefit stream commences abruptly Moderate linear growth	Benefit flows commence at year 2 Benefit stream commences abruptly Moderate linear growth	Benefit flows commence at year 2 Benefit stream commences abruptly Moderate linear growth	Benefit flows commence at year 2 Benefit stream commences from low or zero base Strong non-linear growth
Time profile of costs	Large costs occur over several years Future maintenance and operational costs comparatively negligible	Initial year 1 cost followed by fairly uniform significant cost savings over lifetime relative to base case, with exception for periodic maintenance	Initial year 1 cost followed by slightly volatile but significant cost savings over lifetime relative to base case, with exception for periodic maintenance	Initial year 1 cost No future maintenance and operational costs relative to base case
Absolute impact from lower discount rate	Strong improvement Extending analysis period has very strong impact	Strong improvement	Medium impact	Strongest absolute improvement, but limited data available. Extending analysis period had very strong impact
Relative impact	Strong impact, particularly if analysis period extended	Strong impact, reinforced by further tightening of budget constraint	Strong impact, reinforced by further tightening of budget constraint	Strong impact, perhaps even more so than motorway projects

* VOC = vehicle operating costs

Table 12.1 (cont.) Summary of analysis results of a lower discount rate

Details	**Project type**			
	New and improved cycling networks	**Safety improvements**	**Bridge renewals**	**Travel behaviour change**
Nature of benefit	Walking and cycling benefits	Accident reduction	Travel time savings	Travel behaviour change benefits
Time profile of benefits	Benefit flows commence at year 2 Benefit stream commences from zero base Strong linear growth	Benefit flows commence at year 2 Benefit stream commences abruptly Little growth projected	Benefit flows commence at year 2 Benefit stream commences abruptly Moderate linear growth	Benefit flows commence at year 2 Benefit stream commences abruptly No growth or reduction Benefit stream ends abruptly at year 10
Time profile of costs	Initial year 1 cost Five-yearly maintenance and operational costs	Moderate year 1 cost Very small maintenance impact	Year 1 cost small in comparison to benefit stream Small maintenance impact	Initial year 1 cost Very small operational cost
Absolute impact from lower discount rate	Medium impact	Medium impact, which improves if benefits are long-term (>25 years)	Medium impact, which improves if benefits are long-term (>25 years)	Lowest proportional increase in BCRs
Relative impact	Low performer relatively, because of the very low initial benefits	Low to medium performer, because of the relatively limited and/or static growth in benefit stream These projects may have a longer analysis period, which would improve rankings	Medium performer; improves if longer analysis period applied	Low performer relatively because of the absence of any growth in the benefit stream

Table 12.1 (cont.) Summary of analysis results of a lower discount rate

Details	Project type				
	Preventive maintenance	**New and improved walking networks**	**Congestion improvements**	**Public transport construction works**	**Public transport services (non-commercial initiatives only)**
Nature of benefit	Cost savings	Walking and cycling benefits	Travel time savings	Travel time and VOC savings	General benefits estimated from change in consumer surplus inferred from prices
Time profile of benefits	No benefit stream. The focus is on cost profile only	Benefit flows commence at year 2 Benefit stream commences from zero base Strong linear growth (7.3% p.a.)	Benefit flows commence at year 2 Immense growth for first several years followed by benefit reduction and then a constant benefit stream	Benefit flows commence at year 2 or longer for major works Benefit stream commences abruptly	Benefit flows commence at year 2 Benefit stream commences abruptly
Time profile of costs	Initial year 1 cost Significant cost savings in years shortly after year 1 of same or higher magnitude	Initial year 1 cost Negligible maintenance and operational costs	Initial year 1 cost only relative to base case	Initial cost and maintenance impacts similar to new and improved roading projects	Low initial costs relative to ongoing costs to subsidise operations
Absolute impact from lower discount rate	High impact, as cost-saving initiatives receive high priority	Strong improvement	Medium impact	Medium impact	Improvement offset by greater present value of future costs
Relative impact	Strong impact, reinforced by further tightening of budget constraint	Low performer relatively, because of the very low initial benefits	Low to medium performer because of the relatively limited and/or static growth in the benefit stream These projects may have a longer analysis period, which would improve rankings	Medium performer, probably performing similarly to congestion improvement projects	Low performer, given relatively high impact on future costs and its analysis period, which may only be 10–15 years

12.2 Discount rate results with a 25-year analysis period

12.2.1 General comments

Section 12.2.2 provides a brief description of the undiscounted benefit and cost streams, and the effects of different discount rates on different CBA metrics are discussed in section 12.2.3 (with a full account in appendix B). Section 12.2.4 provides aggregate results and a discussion.

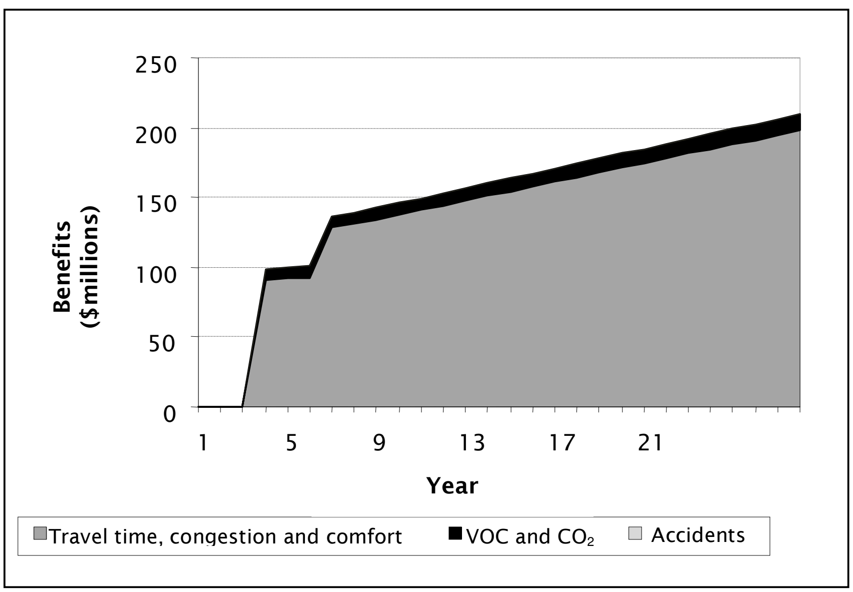
Some types of projects will have lives far in excess of 25 years – which was the maximum length advised in the EEM prior to the reduction in the discount rate from 10% to 8%, which extended the appraisal period to 30 years. While the effects of initiatives need to be appraised over their whole economic lives, either explicitly or by use of a residual value, pragmatic assumptions are made to simplify the analysis and limit the appraisal period to only include effects that are significant in present value terms.

This section considers the standard 25-year analysis period, while section 12.3 provides considers a much longer analysis period for some types of projects.

12.2.2 Description of project types' benefits and costs

Eleven project types have been evaluated. The time profiles of the benefit types, and benefit and cost flows for motorway construction projects, and seal extension projects are described below. The remaining project types are provided in appendix A.

Figure 12.1 Average time profiles of undiscounted benefits for two motorway construction projects



The benefit streams of motorway construction projects (figure 12.1) are characterised by a significant delay caused by construction and are measured in the hundreds of millions of dollars annually. They are predominantly comprised of travel time savings and congestion savings, and have strong linear growth projections.

The cost streams (figure 12.2) are large (an average present value of $250m in investment costs) in the first few years with small ongoing costs to maintain the new infrastructure.

Figure 12.2 Average time profiles of undiscounted costs for two motorway construction projects

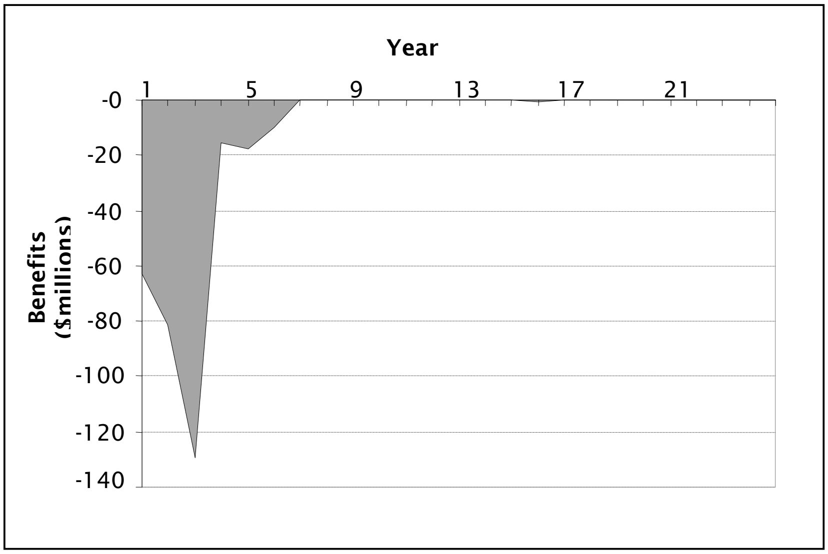


Figure 12.3 Average time profiles of undiscounted benefits for 50 seal extension projects

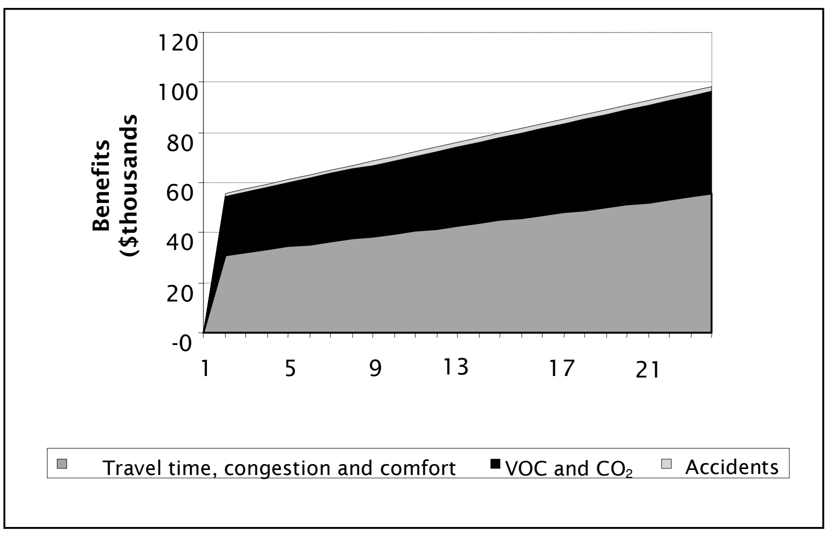
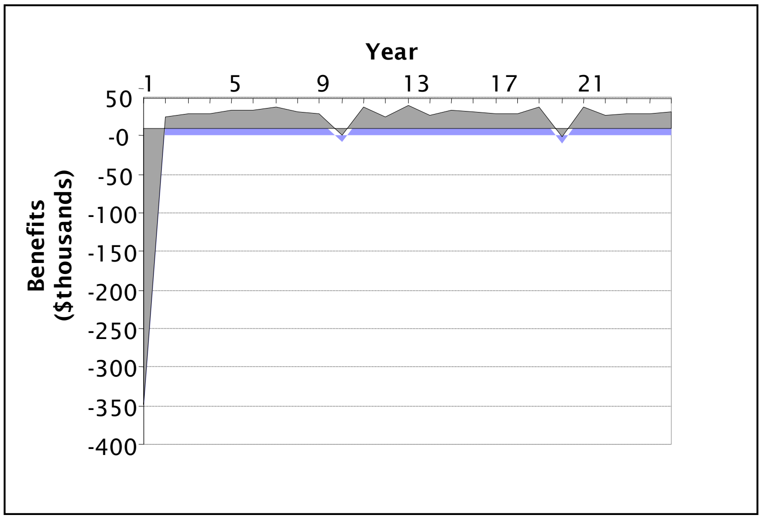


Figure 12.4 Average time profiles of undiscounted costs for 50 seal extension projects



The benefit streams of seal extension projects (figure 12.3) commence in the second year of operation and are made up of travel time savings (30%), comfort benefits (26%), vehicle operating costs including CO_2 (42%) and a small contingency for accident savings benefits (2%). The analysis is based on simplified procedures where a single linear growth rate over the analysis period is judged to be sufficient.

The cost streams associated with seal extension projects are shown in figure 12.4. An initial cost of $350k is incurred on average in the first year. Ongoing cost savings continue over the next 25 years thereafter except for years 10 and 20 when periodic maintenance of the seal is undertaken. These cost savings are measured against a base case of continued maintenance grading and metal costs. The economic benefits of the base case compared to the do-nothing scenario are not evaluated because the do-nothing scenario is not a credible scenario that justifies evaluation.

12.2.3 Effect of discount rate reductions on BCRs

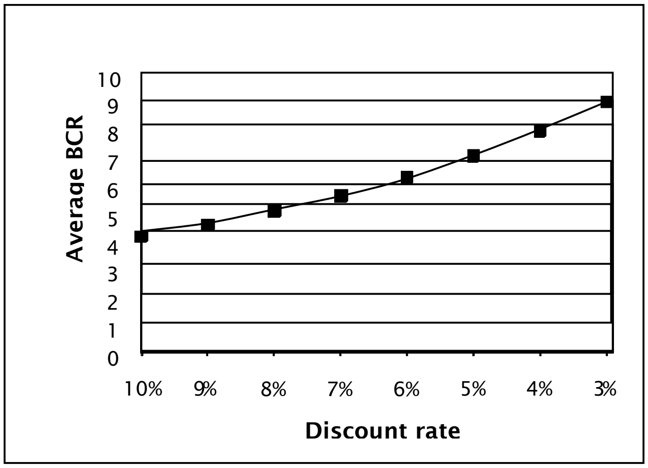
12.2.3.1 Basis and scope

A full discussion of the individual impacts on CBA investment criteria for each project type appears in appendix B. A summary of the effects on motorway construction and seal extensions projects are presented here.

The effects are assessed based on the existing BCR formulation and the NBIR using different assumptions regarding future cut-off BCRs, such as a range of values that are constant as the discount rate is lowered and a value that is raised as the discount rate is lowered. Impacts on NPVs are not reported because they are not suitable where budget constraints are in place.

12.2.3.2 Motorway constrction projects

Figure 12.5 Effects of reducing the discount rate on the BCR of motorway projects

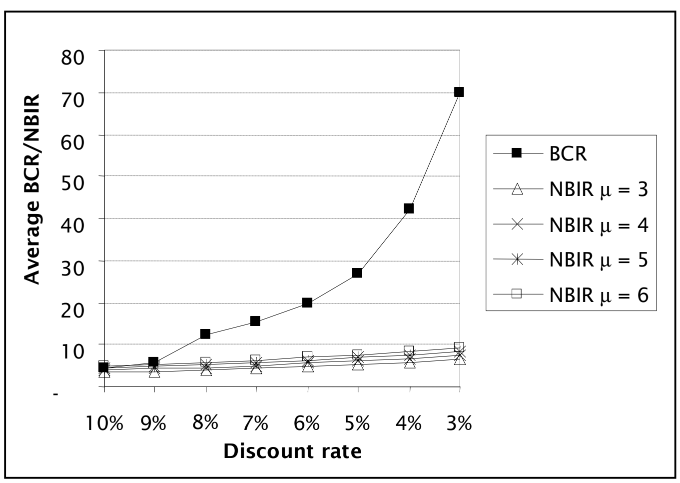


The BCR rises gradually from 4.1 to 8.9 across the range of discount rates (10%–3%) as shown in figure 12.5. The current BCR and the NBIR are practically identical because future costs are insignificant for motorways projects.

12.2.3.3 Seal extension projects

Figure 12.6 illustrates the effect of reducing the discount rate on the standard BCR and on the NBIR for a range of future cut-off BCRs.

Figure 12.6 Effect of reducing the discount rate on the BCR/NBIR of seal extension projects



The effect of reducing the discount rate on the BCRs of seal extension projects has been discussed earlier and was a motivating factor for conducting the review of the BCR formulation. Seal extensions are motivated by both user benefits and cost savings. Generally, the cost savings alone are insufficient to justify the investment and are supplemented in the evaluations by benefits to travellers. When the discount rate is reduced, the projects can often be justified on cost alone, in which case, the BCR becomes undefined or meaningless and is designated a value of 99 – effectively 'just do it' on the basis that it is the do-minimum action.

While such a binary 'go/no-go' decision might be adequate for individual project level decisions, it is not insightful for aggregating or comparing multiple projects, nor for comparing across project types. The standard BCR in figure 12.6 rises sharply as the discount rate is reduced because the projects assigned BCRs of 99 drag up the average. (Were BCRs not capped at 99 then the graph would appear chaotic, as individual projects would have unique hyperbolic functions – refer to figure 10.1 on page 64.)

Figure 12.7 shows the effect on just NBIRs for a range of values for the future cut-off BCR. An increasing value of the future cut-off BCR was applied on the assumption that as the discount rate lowers, the budget will not expand at a rate capable of maintaining the original cut-off BCR.

No modelling of this parameter could be undertaken in this study. The parameter would probably increase in a way similar to project BCRs in general: the increase would need to be progressive and modest, and start at a broadly plausible level, say 3 or 4. Table 12.2 outlines the values assumed, based broadly on the way the BCRs of motorway projects increased. The BCRs of motorway projects were chosen as a broad baseline for these reasons:

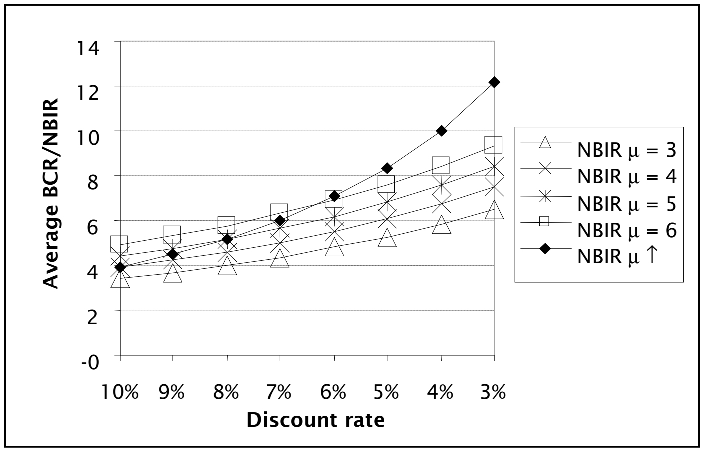
- The path of increase appears plausible – the average BCRs of the motorway projects for which data was available rose from 4.1 to 8.9 as the discount rate reduced from 10% to 3%.
- Motorway projects did not respond peculiarly as the discount rate was reduced, as the effect of maintenance and operational costs are negligible (they are one of the few project types for which the BCR/NBIR was not affected by any assumptions of the future cut-off BCR).
- Motorway projects are large compared to the size of the transport budget meaning that their BCR performance is more relevant than the BCR performance of smaller project types.
- The data obtained for motorway projects appeared to be a good representation of such projects.

Table 12.2 Assumed increase in future cut-off BCR (used for all projects)

Discount rate	Assumed future cut-off BCR as function of the discount rate
10%	4
9%	4.5
8%	5
7%	5.5
6%	6
5%	7
4%	8
3%	9

Figure 12.7 illustrates the effect of a lower discount rate on the NBIRs. Because seal extension projects save costs in the future, a higher value of the future cut-off leads to a higher value of NBIR for any given discount rate. NBIRs steadily increase in performance from 3.9 to 7.5 when $\mu = 4$, increasing from 4.9 to 9.4 when $\mu = 6$, and increasing from 3.9 to 12 when μ increases in line with that assumed in table 12.2.

Figure 12.7 Effects of reducing the discount rate on the NBIR of seal extension projects



The NBIR in the context of seal extensions is a useful substitute measure that can provide insights into how the economic performance of the group of seal extensions is affected by changes to the discount rate.

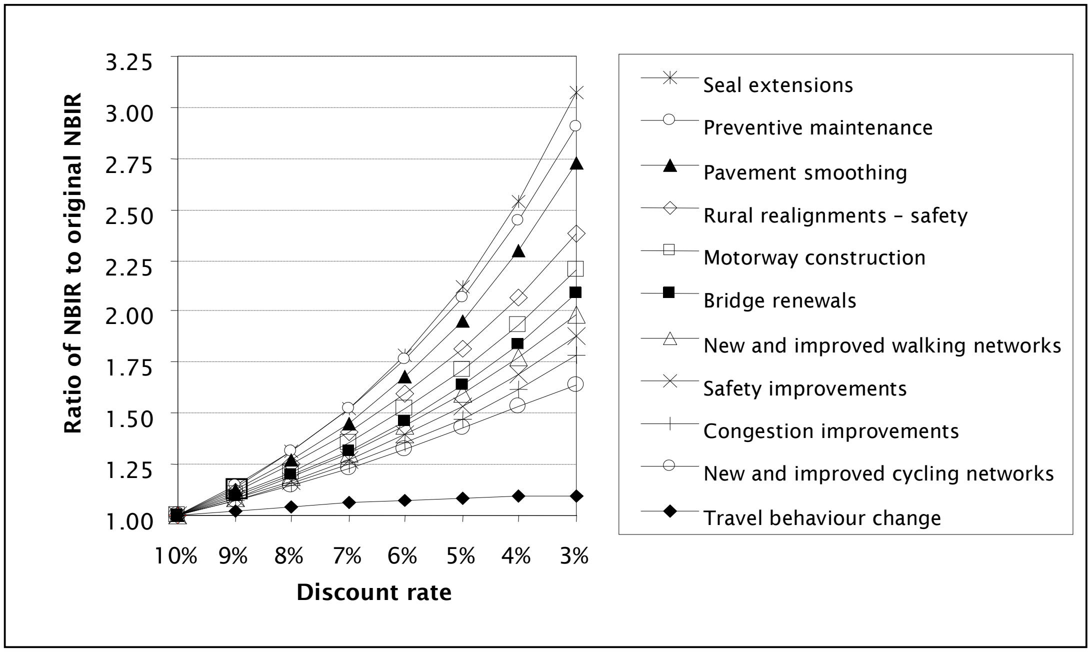
12.2.4 Comparative results and implications

12.2.4.1 Aggregate impact of discount rate

After applying a range of BCR constructs to all the project types (outlined in appendix B), we judged that the NBIR with an increasing future cut-off BCR in accordance with table 12.2 was the most informative and comparable version of the BCR to consider the effect of a reduced discount rate. The choice to use the NBIR over the existing BCR formulation had no effect on several project types that did not have a relatively material impact on future budgets.

Figure 12.8 displays the relative impact of a discount rate reduction on the NBIR, noting that certain project types are more responsive than others.

Figure 12.8 Indexed NBIR performance, with μ increasing as the discount rate reduces



Maintenance oriented projects have the largest relative improvement as the discount rate is reduced, with seal extensions at the top of the list, followed closely by preventive maintenance and pavement smoothing. Inspection of their NBIR plots indicates their performance is helped significantly by the rising cut-off BCR as the discount rate is reduced.

As the discount rate is reduced, the budget becomes more constrained, meaning every dollar in the budget is more and more valuable. Any project that releases an extra dollar of cost is valued more than any project that produces an extra dollar of benefit.

The fact that maintenance oriented projects fare most strongly is a notable result, as the current funding allocation framework provides first priority of funds to maintenance activities, with whatever remains allocated to construction projects.

If we exclude consideration of maintenance oriented activities, motorway construction projects also fare strongly, and are second only to rural safety realignments. (Bear in mind that only two project evaluations for each of classes were obtained; the motorway projects appeared more representative but the rural safety alignment projects were skewed by a single project.)

The performance of bridge renewals followed closely behind motorway construction projects, with walking network projects ranking next. Safety improvement projects and congestion improvement projects did not improve as much as most other projects because their time profiles of benefits, while strong, are quite flat (refer to figures A.11, A.12, A.20 and A.21 in appendix A) and their benefits are smaller, with a lower discount rate than projects that forecast growing benefits.

The level of improvement for new and improved cycling network projects was relatively low, not because growth trends were low, but because benefit streams start from a very small level, unlike most other projects, which have significant benefits come on-stream at year 1. Walking network projects fared much better than cycling network projects, as walking network projects, on average, assumed a linear growth rate of 7.3% per annum compared to cycling network projects, which assumed a 4.6% (linear) growth rate.

Travel behaviour change projects improved but performed unfavourably relative to all other project types. This is attributed to the absence of growth assumed in annual benefits. Although the effects are assumed to last for 10 years, and thus are not natural beneficiaries of a lower discount rate and a longer-term view, controlling for the shorter life through an annual equivalent measure did not materially alter this result.

Sensitivity testing of the future cut-off BCR parameter did not significantly alter the general trend of projects: higher future cut-off BCRs exaggerated the extent of the spread and lower values mitigated the extent of the spread.

12.2.4.2 Alternative intuition using the standard BCR approach

The points covered in the previous section are based on application of the NBIR, but it is important to rationalise them in terms of the existing BCR formula and the existing NPV cost-minimising criterion for maintenance projects. The following outlines this for pavement smoothing and seal extensions.

- A lower discount rate increases benefits on the numerator and lowers the whole-of-life costs on the denominator, and thus BCRs rise.
- The lowering of the denominator has an increasing proportional impact on the overall BCR as the discount rate is reduced. This is akin to a multiplier effect discussed in chapter 11, as cost savings are implicitly factored up by an expectation that the future cut-off BCR rises in direct proportion to project BCRs.
- BCRs rise sharply (for example, refer to the BCRs shown in figures B.1, B.2, B.10 and B.11 in appendix B), perhaps even being capped at 99, and projects receive priority funding.

Further, most projects with lower whole-of-life costs than their base cases receive funding with no further economic evaluation necessary because they become defined as the do-minimum.

12.2.4.3 Public transport services

Unfortunately, no suitable evaluations were obtained on public transport service projects after an assessment of every project we were able to view (such evaluations were not available from the NZTA directly). However, we can comment on possible effects, given the broad characteristics of public transport services, and the intuition learned from the other findings of this study.

- Public transport projects within the NZTA's mandate span construction works such as new bus lanes or corridors, and operational costs such as subsidies for public transport operators.
- While a lower discount rate benefits all land transport projects directly, the secondary effect of higher future cut-off BCRs can be just as influential on project performance. This factor affects those projects that have large positive or negative effects on future budgets relative to the size of the initial investment.
- We expect that the effect of a lower discount rate used on public transport construction works will be similar to standard road construction projects, with a similar length of economic life and a similar need for periodic maintenance.

- However, public transport operations activities may be significantly negatively affected relative to other project types. Given the potential for much higher future cut-off BCRs, the future operating costs are more heavily weighted, which offsets the extent to which BCRs increase (this factor works in the favour of maintenance oriented initiatives). A new public transport service may incur very little, if any, up-front cost relative to ongoing costs from future budgets. If future cut-off BCRs were, say, 10, then the benefits in each year of operating would (on average) need to be about 10 times the cost of the yearly subsidy every year on average for the project to exceed the opportunity costs from the wider transport budget.
- This negative impact will be offset to an extent if public transport operations reduce usage of competing transport modes and thus provide reductions in maintenance costs across the wider network. However, this cost saving is likely to be smaller than the annual operating costs of new operations and such mitigation will be limited.
- The relative attractiveness of public transport operations may reduce relative to other investment types, depending on the size of budgets (and hence cut-off BCRs), and the quality and durability of the existing stock of infrastructure. (That is, the higher the quality of existing infrastructure, the lower the maintenance and operational requirements, and the more funds available for operating existing public transport operations and commissioning new ones.)
- Revising particular unit cost values that perhaps themselves are a function of the discount rate, such as those that represent health and environmental impacts, would contribute to offsetting the decline in relative priority, although just how much is unknown at present and this is beyond the scope of this study.

Furthermore, page 5–8 of Volume 2 of the EEM suggests that a shorter analysis period of 10–15 years may be appropriate for passenger transport services, which would reduce the comparative benefit that a lower discount rate would provide.

This rationale is based on application of the NBIR, but the intuition can be alternatively be expressed in terms of the existing BCR formulation.

- A lower discount rate improves benefits on the top line, but increases the whole-of-life costs on the denominator. While BCRs for public transport operations would rise, they rise less than general project types and much less than maintenance oriented projects that decrease future costs.
- The rise in BCRs incorporates a feedback effect that slows the rate at which BCRs increase, as cost increases are implicitly multiplied by an implicit expectation that the future cut-off BCR rises in direct proportion to the (subdued) rise in project BCRs.
- Thus for public transport operations BCRs rise slowly relative to other project types and many of these projects would as a result receive less funding.

12.3 Discount rate results with an extended analysis period – 80 years

12.3.1 Longer life spans in practice

Section 12.2 began by noting that although the appraisal periods for projects should cover the entire economic life of initiatives, in practice, it is limited for long-life initiatives by the discount rate used. The common practice in CBAs generally is for impacts occurring after a specified period to be appraised but represented as a separate 'residual value'; this means the actual period of time appraised can differ significantly from the official appraisal period. However, the EEM disallows this by stating that because of discounting, it will have 'only a small impact on the appraisal and shall generally be omitted.'

Although the EEM seems to provide some flexibility in this, first-hand experience indicates this is interpreted rather literally throughout the sector and exceptions are rare. An exception was the case for tolling the Western Ring Route (Hyder 2007), but some recent CBAs of two Roads of National Significance projects – the Waikato Expressway and Transmission Gully[23] – did not consider benefits beyond 30 years once the projects are finally complete (Hyder 2009a and Hyder 2009b), which is critically important for proper sensitivity assessments of the discount rate.

Thus although theoretically the discount rate should not guide the appraisal period, in practice, a lower discount rate needs a much longer maximum appraisal period for long-lived projects.

The analysis in section 12.2 used the existing project evaluations as they were and assessed the relative effects of a discount rate reduction on them. This section will consider how the effects might differ if a much longer analysis period were used.

At the lowest plausible discount rate, the present value of $1 of benefits in year 80 would be about $0.09 at a 3% discount rate, similar to what $1 of benefits is worth at year 30 under an 8% discount rate. This would mean that for some major infrastructure investments with very long lives, the appropriate appraisal period could potentially be over 2.5 times longer than the current period of 30 years.

12.3.2 Issues pertaining to projecting costs and benefits over long analysis periods

12.3.2.1 United Kingdom guidance on assessing long-life transport projects

As the United Kingdom has recently reduced its discount rate to 3.5%, with a declining discount rate schedule for long-term benefits, it has had to consider how to appraise projects over longer periods. The DfT (2007) has issued helpful guidance and discussion on how to evaluate projects that have long-term benefit profiles. The guidance most relevant from the DfT on projecting costs and benefits is quoted below (emphasis added).

[23] Strictly speaking, Transmission Gully is one possible, albeit important, component of the overall Wellington to Levin Road of National Significance.

Indefinite life projects

For many transport investments, including most road, rail and airports infrastructure, the expectation is that maintenance and renewal will take place when required. Once in place, future decisions are concerned only with upgrading or (rarely) closure, against a 'without project' case that would include sufficient maintenance and renewals investment to maintain the existing infrastructure. Under these circumstances, it is very difficult to determine the 'period of usefulness' of the project – these projects have an indefinite life.

<u>For these projects, the appraisal period should end 60 years after the scheme opening year.</u>

Residual values for indefinite life projects

For projects with indefinite lives, it is inappropriate to estimate a residual value based on resale or scrap value. Depending on what is assumed about the growth and decay in the magnitude of benefits, these projects will continue to generate benefits for more than 60 years after opening. In principle, these additional benefits represent the residual value of a project with indefinite life. In practise, they could most efficiently be estimated by extending the appraisal period. But, for projects with indefinite lives, it is not clear how far beyond 60 years after opening the appraisal period should be extended. ***<u>The Department is giving further thought to this issue and expects to issue further guidance in due course</u>****. In the interim, residual values should not be included in the appraisal of projects with indefinite lives. However, analysts may wish to estimate residual values for these projects as a sensitivity test. These estimates should be made by extending the appraisal period beyond 60 years after opening. Analysts will need to explain very clearly the reasons for their choice of a revised end point for the appraisal period.*

Forecasting the long-term

<u>In most cases, this can only be achieved by extrapolation and assumption – formal modelling and detailed analysis is unlikely to be feasible or worthwhile</u>. *For most projects, formal modelling will not be practical for forecast years more than 15–20 years after project opening. This is because the local data needed to ensure that results are credible is not available that far into the future. Analysts are encouraged to choose a last forecast year as far into the future as is practical.*

It is not credible to assume that the magnitude of benefits will increase indefinitely (if at all) after the last modelled year. Analysts will, therefore, need to specify a profile of growth and decline in the magnitude of benefits beyond the last modelled year. In particular, they will need to consider:

- *Whether the magnitude of benefits will continue to grow after the last modelled year and, if so, at what rate; and*
- *Whether the magnitude of benefits will decline in the future and, if so, at what rate and from when.*

Growth in the magnitude of benefits will largely be driven by growth in usage. In particular, it will generally be reasonable to assume that growth after the last forecast year is not higher *than that implied by formal modelling up to the last forecast year.* ***A sensitivity test assuming zero growth from the last forecast year is recommended for most schemes.***

Operating, maintenance and renewal costs

For projects with indefinite lives, the extension of the appraisal period from 30 to 60 years after opening may bring additional elements of major structural maintenance and/or renewal within the appraisal period. For example, road pavements and drainage may require renewal, as may rail track and rolling stock. Wherever possible, the timing, cost and duration of these major elements of cost should be estimated explicitly. Where this is not possible, these costs may be included in annual maintenance rates, though care must be taken to avoid underestimation. Major maintenance and/or renewal may cause delays and other disbenefits to users. Where this is the case, estimates of the disbenefits caused must be made and taken into account.

This guidance outlines the ambiguities of extending the analysis period out more than 60 years. We are not aware of the DfT issuing further guidance on how to appraise projects that have lives longer than 60 years as mentioned above.

12.3.2.2 Other uncertainties and issues regarding long-term appraisal periods that would require further consideration

The United Kingdom's transport sector has some contention about how meaningful it is to measure benefits out further than 30 years[24]. One of the key concerns is how relevant the do-minimum base case is out past 30 years, as ongoing traffic growth and regulatory requirements would need further significant investment of some sort at some stage.

The key implication of low discount rates is that evaluators must be even more diligent when canvassing all the viable options that are available to decision makers, particularly the long-term timeframes for all such options. An extended analysis period may warrant more options to be explicitly analysed. Specifying the base case would be more difficult if a typical do-minimum strategy (with little or no investment costs) cannot be sustained over the entire analysis period, say because some major investment in that corridor is inevitable. If the base case involved significant investment costs at some stage this would affect the benefit flows of the initiatives (conceivably even ceasing them altogether). Substantial investments within the base case scenario could imply cost savings of an equal magnitude in the option scenario, especially at the end of an analysis period when benefits henceforth cease.

This is common for preventative maintenance projects, where the two options are to either incur costs now or incur them later: any benefits to users of the 'do it now' option cease once the base case cost is incurred, but the (generally larger) cost savings offset the cost of doing it now. Thus although the economic life of the asset may last several decades, the CBA need only extend to the end of the investment in the base case.

Similar considerations to this should be considered for long-term appraisals, but on a grander scale. If a major motorway investment was inevitable, say in 40 years' time, then undertaking it now brings forward benefits that it would have occurred anyway, but not before a major (future value) cost is saved, offsetting the cost of undertaking it now.

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[24] Observation based on Hyder conversations with UK staff.

Thus defining the base case in the long-term can be very important to the appraisals of long-term infrastructure. This can be exceptionally difficult for major investments that affect the national transport network or regional transport network, given the vast array of alternative complementary and substitute investments (including multi-modal projects), and given an aversion towards pre-existing regional transport plans and strategies being subject to any further CBA scrutiny.

Such long-term scenario planning might require fundamentally different techniques to be devised and considered for transport planning. For major network investments, it might be helpful to consider a 'backwards induction' approach rather than the current 'forwards induction': commence the analysis at one or more 'end points' – long-term ultimate configurations of the network – and work backwards to determine the best sequence and timing of investments needed to get there. The need to value the preservation of options (option values) for major corridors could be very important in such long-term network-wide considerations, particular for major projects that may substantially change land use patterns, generate more travel than originally expected and have a major degree of uncertainty.

A substantial reduction of the discount rate could significantly increase the amount of resources required to conduct detailed CBAs and require fundamentally different approaches to integrating CBA with long-term transport planning and land use planning. A careful appraisal of the issues and problems would be required and solutions developed.

12.3.3 Time profile of benefits and costs over an 80-year analysis period

Two key issues arise about projecting benefits and costs into the future: what assumptions to make about benefit flows, and what costs are involved to maintain and renew the projects.

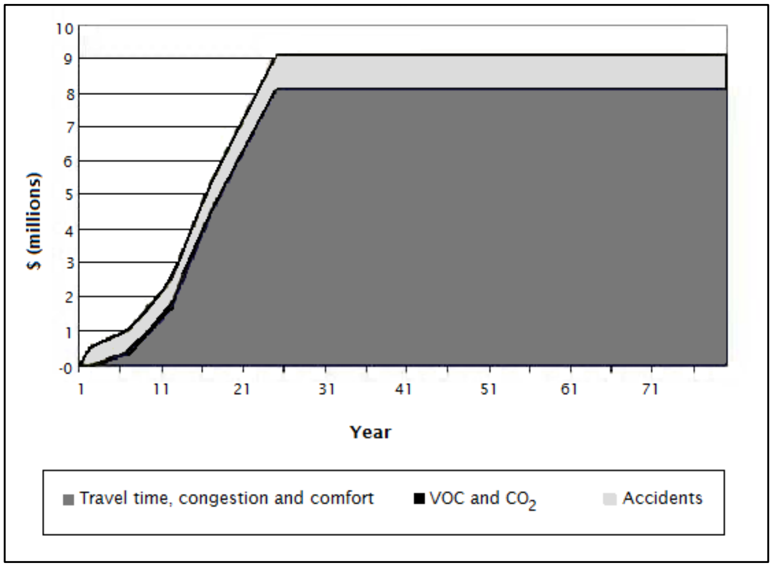
One issue with our data is that road pavement surfaces are not long-life (40+ years) and typically need full replacement at 25 years, which conveniently coincides with the analysis period of the data available. Thus, we do not have the basis needed to make meaningful long-term projections of costs and benefits for maintenance oriented projects and small general projects that have large renewal costs relative to initial construction costs.

The benefit streams of motorway construction projects and other larger projects, on the other hand, could be projected forward because the pavement renewal costs at about year 25 will be small compared with initial construction costs and they should also not be affected by assumptions about future budget constraints. While ignoring this issue is not ideal, it should still allow reasonable insights for projects not characterised by their pavement surfaces, such as projects with new or substantially improved alignments and/or infrastructure. The project types analysed in this way are:

- motorway construction projects
- rural safety realignments projects
- safety improvement projects
- bridge renewals
- congestion improvements.

Given the speculation involved in projecting these benefit and cost streams, a somewhat conservative approach was taken to project the final year's net benefits forward at 0% growth. This is one technique adopted in the United Kingdom. An example of the time profile is shown in figure 12.9.

Figure 12.9 Demonstration of extending a uniform benefit stream (rural realignments) to year 80



In what follows, the analysis period is stretched to 80 years and is assessed using the 3%–10% range of discount rates.

Not all of these projects would have benefits lasting this long for the reasons outlined in section 12.3.2, such as an asset life less than 80 years or a base case with a similar investment occurring within 80 years. However, this still serves as a useful 'what-if' assessment.

Our prior expectation is that BCRs would not change significantly when evaluated at the current 10%, because of the guidance by the Treasury (2005) and the EEM that benefits after 25 years are discounted away to insignificance at a 10% discount rate.

12.3.4 Long-term effects of discount rate reductions on CBA investment criteria

This section summarises effects for motorway construction projects only. Appendix C contains the effects for rural safety realignments projects, safety improvement projects, bridge renewals and congestion improvements.

Figure 12.10 indicates an abrupt cut-off in the measurement of the benefit stream at end of year 28[25] for motorway construction projects at lower discount rates. Given the long life of new motorway constructions, this outcome is undesirable when lower discount rates are applied. Figure 12.11 outlines what discounted benefits would be measured if undiscounted benefit and cost streams were projected as outlined above.

[25] The EEM permits the analysis period to be extended past 25 years to account for a construction period of longer than one year.

Figure 12.10 Discounted benefit and cost streams to year 35 (standard analysis period) for motorway construction projects

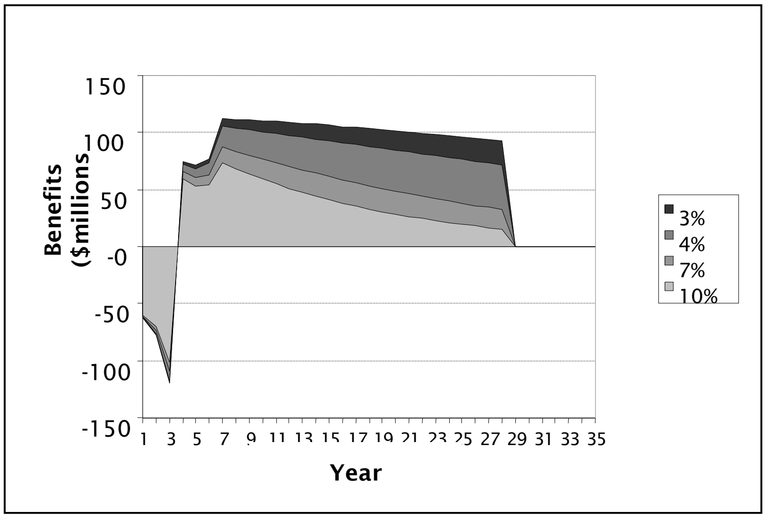
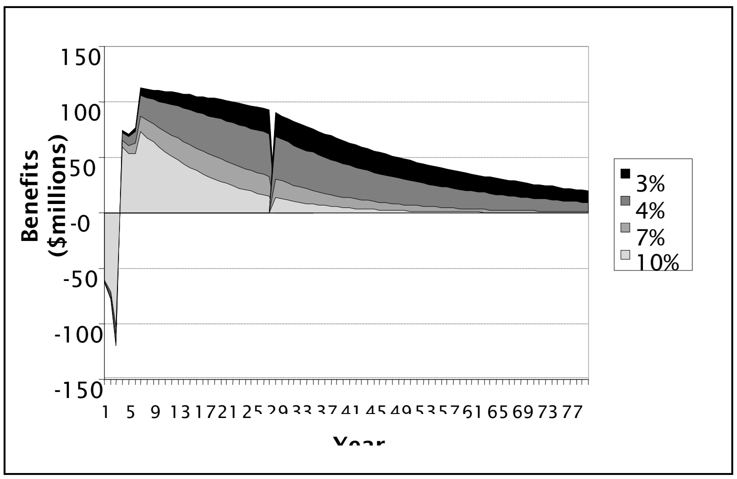


Figure 12.11 Discounted benefit and costs streams to year 80 for motorway construction projects



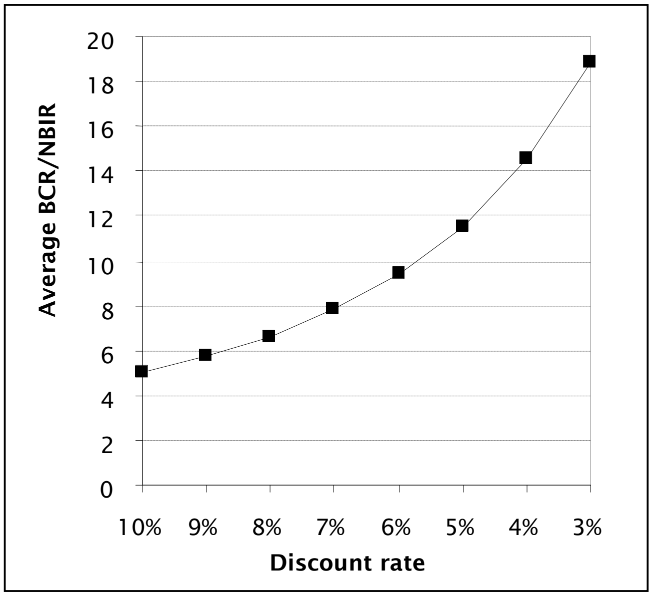
These figures indicate that at discount rates of 3%–4%, immense additional benefits are potentially captured; at 10%, the additional benefit streams are relatively minimal. Table 12.3 summarises the impacts on BCRs and NPVs.

Table 12.3 NPVs of motorway construction projects with different analysis periods

Discount rate	28-year analysis period		NPV of analysis period years 26–80 ($millions) (% of 25-year value)	Total with 80-year analysis period	
	(unconstrained) NPV $millions	BCR		(unconstrained) NPV $millions	BCR
10%	764	4.1	152 (20%)	916	5.0
7%	1189	5.6	452 (38%)	1642	7.8
4%	1903	7.9	1551 (81%)	3454	15
3%	2244	8.9	2434 (108%)	4678	19

At 10%, the average BCR increases significantly from 4.1 to 5.0, and thus it could be possible to extend the analysis period for long-life investments further than that advised in the EEM. Furthermore, the BCRs at a range of discount rates are much higher under the extended analysis period. At a 3% discount rate and with the extended analysis period, BCRs are up to five times higher than at 10% and 25 years. If undiscounted benefits continued to grow after 28 years – which they often would – then BCRs could be much greater again. Figure 12.12 displays the steep increase in the BCR as the discount rate is reduced.

Figure 12.12 BCRs of motorway construction projects – 80-year analysis period



12.3.5 Comparative results and implications

Figure 12.13 shows how the project types performed on a relative basis when the selected project types are evaluated over 80 years (the remaining project types still have an analysis period of 25 years or less). The future cut-off BCR was again supposed to be similar to those of motorway projects, which in this case would only come about if a severe shortage of funds occurred at an extent that is perhaps not likely, although if benefits were presumed to grow after 25 years, and if a declining discount rate schedule was used, then BCRs could be substantially higher at low discount rates, suggesting it is perhaps not totally implausible. (Note that it is not assumed that the budget would actually contract but that the demand for funds would be so much stronger.)

Figure 12.13 BCR impact over an 80-year analysis period for selected projects under extreme budget constraints

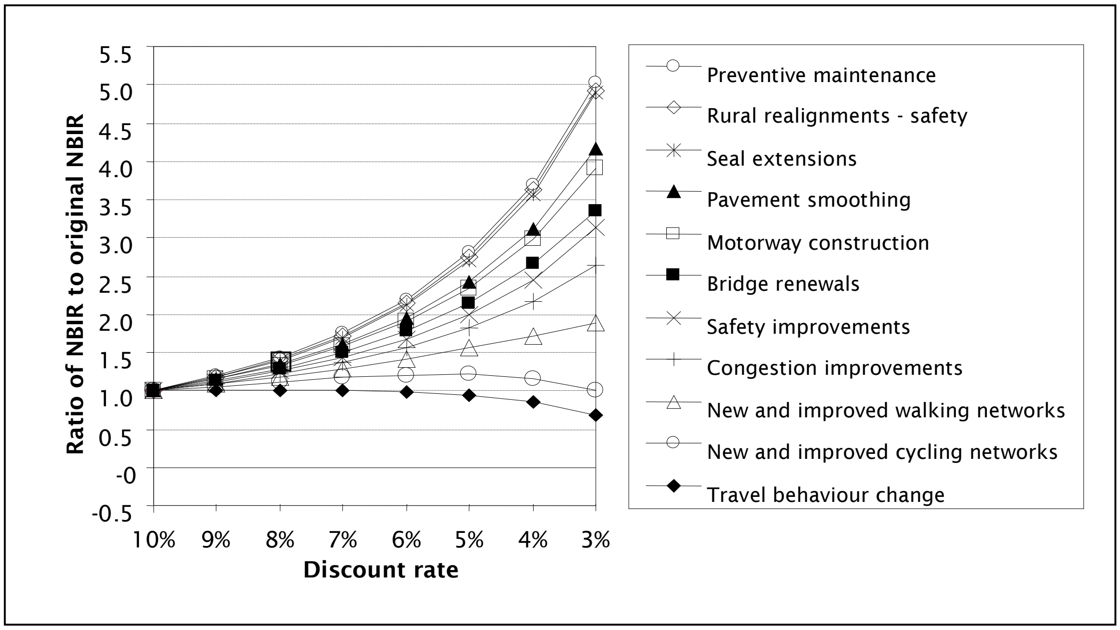


Table 12.4 Extremely high future cut-off BCRs in the very long-term 'what-if' test

Discount rate	Assumed future cut-off BCR as function of the discount rate
10%	5
9%	6
8%	7
7%	8
6%	10
5%	12
4%	15
3%	20

Again, maintenance oriented projects become the most preferred, somewhat based on an improvement from a lower discount rate but mainly from the raising of the future cut-off BCR when other projects have such high BCRs.

Rural safety realignment projects are the top performer across construction oriented projects. As one would expect, motorway projects are very favourably affected among construction projects given low discount rates and long analysis periods. The remaining projects that were extended also strongly benefit.

Walking and cycling projects, and travel behaviour change projects do not perform as strongly with a decrease in the discount rate, with the latter two even disbenefiting at low discount rates as a direct consequence of the extremely high future cut-off BCR simulated in this instance.

13 Effect of the discount rate on project specifications

13.1 Aims

Prior to undertaking the research, we hypothesised that a lowering of the discount rate would not only alter the relative rankings of projects, but would alter the specification of projects by increasing their robustness and quality. This chapter considers the impact of the discount rate on pavement selection, which is a major component of the cost of general road improvements and maintenance.

A review of previous literature indicates that the economic viability of long-life pavements is greater than previously appreciated, to the extent that they may have been economic even at the previous 10% discount rate. This chapter summarises a variety of potentially important impacts that are typically excluded from the evaluations of pavements or not appropriately captured, and also summarises how the use of the recommended comprehensive NBIR for a BCR formulation is an ideal way to consider these wider impacts.

13.2 Previous evaluation of long-life pavements

New Zealand roads are typically designed to last 25 years, which, by coincidence, was the NZTA's required analysis period at the previous 10% discount rate. The term 'long-life pavements' is given to pavements with design lives of 40 years or more.

Our analysis of the effect of the discount rate on the evaluation of long-life pavements in New Zealand has highlighted a potentially significant oversight in previous evaluations relating to the treatment of options of varying length lives.

Deakin (2002) researched the application of long-life pavements in New Zealand, including an evaluation of their economic viability. Tables 13.1 and 13.2 show the non-discounted and discounted real cashflows of two pavement options: standard asphalt and long-life asphalt options for an area of 1000m^2.

Table 13.1 Cashflow profile of 160mm structural asphalt pavement (2002 dollars, 10% discount rate)

Description	**Amount**	**SPPWF[a]/ USPWF[b]**	**Discounted cost**
Cost works ($80/m²)	$80,000	0.909	$72,727
Cost annual maintenance year 1			$500
Cost annual maintenance following works (years 2–25)	$250	8.570	$2142
Periodic maintenance costs			
year 8	$20,000	0.4665	$9330
year 16	$20,000	0.2176	$4353
year 24	$5000	0.1015	$508
Total			$14,190
Less year 26 salvage value[c]		$0	$0
Total cost:			**$89,560**

Notes to table 13.1:

a single payment present worth factor

b uniform series present worth factor

c No salvage value is assumed by Deakin (2002). This can be defended by assuming that the economic life is complete by the end of 25 years and that total replacement of the same nature as the original project's construction is required.

Table 13.2 Cashflow profile of 190mm structural asphalt pavement (2002 dollars, 10% discount rate)

Description	**Amount**	**SPPWF/ USPWF**	**Discounted cost**
Cost works ($90/m²)	$90,000	0.909	**$81,818**
Cost annual maintenance year 1			**$500**
Cost annual maintenance following works (years 2–25)	$250	8.570	**$2142**
Periodic maintenance costs			
year 8	$17,000	0.4665	$7931
year 16	$17,000	0.2176	$3700
year 24	$17,000	0.1015	$1726
Total			**$13,356**
Less year 26 salvage value	$33,750 (=$90,000*15/40)	0.0839	**$2832**
Total cost:			**$94,985**
Extra cost of option	$94,985–$89,560		**$5425**

The long-life pavement is characterised by higher investment costs and lower maintenance costs (except for year 24, the last year of life for the standard life option) and it is $5425 more costly in present value terms. The most important aspect to note is the treatment of the 'salvage value' for the long-life option to account for the residual value of the option after year 25, using what might be described as an accounting treatment of the option (straight-line depreciation).

The internal rate of return is the value of the discount rate where the NPV of the option is equal to the NPV of its counterfactual base case, in this case the cheaper option. The approach undertaken by Deakin (2002) indicates that the internal rate of return for the long-life pavement option is **4.8%** – substantially lower than the 10% discount rate of the time, indicating a notable lack of economic viability for the long-life option.

However, CBA textbooks suggest other ways to treat options with longer lifespans. Boardman et al (2006) describe two equivalent approaches which involve either rolling over the same project at the end of its life or determining the project's annual (annuity) equivalent cost[26]. We undertook to roll over these two projects to comparable length lives (included in appendix D) and found that the break-even discount rate for the long-life option is much greater at **8.3%.** This indicates that the long-life pavement option is much more economically viable than previously thought.

Other factors have been excluded from the analysis although they are favourable to the economic viability of long-life pavements:

- the expectation of an increasing real cost of maintenance over time caused by the rising real cost of bitumen
- higher maintenance costs caused by increasing trends to undertake maintenance at night to minimise traffic disruption
- the impacts on road users and the wider community of different pavement options, including the disruption to road users caused by maintenance and construction, and noise and environmental effects
- the nature of long-life asphalt, which requires on partial replacement of the original during 'complete' renewal, as the deeper layers of the pavement are preserved, meaning that subsequent 'rolling over' of projects incurs lower costs
- a greater risk of pavement failure before the end of the design life from some cheaper pavement options, which will affect road users and approved organisations.

These factors would either increase the costs/disbenefits of periodic maintenance activities or lower future renewal costs of the long-life option, improving the cost of the long-life option relative to the standard pavement option. For instance, if real construction and maintenance costs increased by 1% per annum compounding, the discount rate that makes the two options equal [27] rises from 8.3% to about 9.4%.

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[26] Boardman et al (2006) acknowledge that a method exists for estimating salvage value by using a fraction of the initial construction cost, such as was done by Deakin (2002). However, they note that the choice of fraction 'is quite arbitrary. It may bear no relationship to the future net social benefits. Thus this method, while simple, is not intuitively appealing.'

[27] Because some of these considerations serve to alter the future undiscounted costs of each option, the textbook approach of evaluating using annuity equivalents is unsuitable, as that method presumes future cashflows are exact duplicates. Rather, a complete schedule of cashflows for each option should instead be described, with the projects rolled over until the options have comparable lifespans.

Other evaluations of pavements were kindly supplied to us by the NZTA but were commercially sensitive and confidential, and thus not able to be included in this report. These evaluations also showed potential for improving the apparent economic efficiency of long-life pavements by use of the roll-over method.

13.3 Expressing pavement selection assessments by the comprehensive NBIR rather than NPVs

The review of the BCR formulation in chapter 11 described how the comprehensive NBIR is ideal for appraising initiatives that are heavily cost-oriented, with relatively little or no benefits to users relative to the investment, operating and maintenance costs.

The NBIR can be used to appraise initiatives that currently are appraised using NPVs and thus can be more informative to policy makers and decision makers about the economic efficiency of maintenance activities relative to other investment types. Such an approach could helpfully contribute to the identification in the New Zealand Transport Strategy (NZTS) (Ministry of Transport 2008) of the need to 'scope a road surfacing strategy which covers the safety, environmental, noise and lifetime cost/benefits of surfacing options.'

The use of the comprehensive NBIR has the following benefits:

- The effects on road users and the wider community (such as maintenance disruptions, noise reduction performance, improved macrotexture, less rutting and environmental factors) can be easily incorporated on a basis that is consistent with the evaluation of land transport projects in general, which contributes to a more thorough evaluation of options.
- The intuition of the BCR is maintained as well as maintaining the significance of the budget constraint and the subsequent fact that one dollar of cost corresponds to strictly more than one dollar of benefit. This reduces the incidence of mistakes being made whereby benefits to users are included in NPV calculations, which fails to reflect the opportunity cost of funds in the future.
- It maximises NPV from current and future budgets, and, if required, can adapt to any possible substantial change in the size or demand on future budgets over time.

13.4 Summary of the effects of the discount rate on pavement selection

This chapter has highlighted that some potentially important effects and issues may not have been considered or properly considered, and that long-life pavements may be much more economically viable than previously thought.

Evaluators require more guidance on how to compare projects with different timeframes, particularly approaches similar to the 'rolling over the shorter project method' described in Boardman et al (2006). At present, the EEM only states that 'the analysis period for road projects shall start at time zero and finish 30 years (unless otherwise agreed with NZTA) from the year in which significant benefit or cost commences', and rather strict adherence to this guidance may have contributed to this problem. The rolling-over method effectively increases the length of the analysis period, and the guidance in the EEM should be modified to reflect this requirement.

Considering cost effects occurring after 30 years also requires careful consideration of the assumptions regarding the real price movements of future maintenance costs, particularly if the discount rate were lowered.

The comprehensive NBIR formula is much more informative to decision makers, is comparable to general transport projects, and can more readily include important effects on road users and the wider community, as well as reduce the misuse of NPVs in the presence of constrained budgets.

The effect of the range of discount rates has not been explicitly considered. However, a lower discount rate would lead to a more widespread application of long-life pavements.

Because the majority of analysts undertaking the CBA of such initiatives are engineers rather than economists, it might be helpful if the EEM could somehow provide more economic intuition to support the advised procedures without compromising conciseness and the need to have a strong operational focus.

14 Long-term impacts

14.1 Overview of initial findings

The direct results so far reflect alterations to short- to medium-term national transport programmes better than they do long-term steady-state outcomes. This is because the base cases of the CBAs analysed reflect the network as it currently stands. This chapter considers the possible long-term cumulative effects of applying lower discount rates on investment programmes over several decades.

Table 14.1 and the following list summarise the earlier findings and provide a brief explanation for the cause of the impacts.

- **Works to enhance quality and durability** benefit markedly from a lower discount rate and from higher marginal BCRs. These projects, such as pavement smoothing, seal extensions and preventative maintenance, seek to release funding requirements on future budgets. Given the stronger emphasis on long-term outcomes when a lower discount rate is used, any action that relaxes the constraint of future budgets is highly valued when budgets are tightly constrained.
- **Major long-term infrastructure** such as motorway construction, bridges and major road realignments increase in priority. Effects felt in 25+ years would be significantly more relevant but are likely to be based only on extrapolation and assumption, and significant uncertainties exist, including forecasting transport demand in relation to oil price scenarios. However, lowering the discount rate from 10% to 5% could make BCRs of motorway construction projects around two to three times larger (60–80-year analysis periods), which is probably enough to offset majority of downside scenarios.
- **Small to medium-sized works** were not grouped explicitly in the modelling, but such projects will not have as long an economic life as the major investments and will not have as great an increase in BCRs. Given the greater constraints on funds, small to medium-sized works with future cost savings will be favoured over those works that do not.
- **Public transport services:** While specific CBA evaluations were unavailable, an assessment has been made based on general attributes of public transport service projects. A lower discount rate would weight future operating and maintenance costs more heavily, and because future budgets are more tightly constrained, the CBA optimisation process would respond towards these relatively less favourably, all else being equal.
- **Cycling, walking and travel behaviour change** projects would fare unfavourably under a lower discount rate relative to other project types. For walking and cycling projects, this is because the time profiles of benefits commence at very low levels in the first year of operation. For travel behaviour change projects, it is because no growth in benefits is assumed.

Table 14.1 Summary of possible impacts to relative priorities from a lower discount rate

Initiative type	Short-term (0–5 years)	Medium-term (5–25 years)	Long-term (25–60 years)	Very long term (60+ years)
Maintenance	++	++	+	-
Major capital works	++	++	+/++	+/++
Small to medium-sized works:				
User benefit oriented	–	–	~	+
Cost saving oriented	+	+	+	~
Public transport services (non-commercial)	–	–	~/–	+
Walking and cycling	~/–	~/–	~	+
Travel behaviour change	––	––	––	––

++ = large relative increase in priority

\+ = relative increase in priority

~ = no relative change in priority

– = relative decrease in priority

–– = large relative decrease in priority

14.2 Possible long-term effects

14.2.1 Generalisations

After a sufficient period of investment under a lower discount rate, the overall land transport network will improve in durability and quality. Subsequent maintenance initiatives would be evaluated against CBA base cases that are themselves more robust, and the economic efficiency of further upgrades to the network would progressively diminish.

After a sufficient period of investment under a lower discount rate, the transport system would reach a steady state where the legacy of having applied a 10% discount rate since 1971 would no longer be a major influence on investment decisions[28].

Although many life-limited infrastructure assets, particularly pavements, are designed to last only 25 years, the new steady state may take two to three life cycles (perhaps 60+ years) to happen, depending on the change in the discount rate. Factors influencing this include budget restrictions on maintenance to ensure enough funds are available for other types of initiatives, and a need to upgrade progressively so the quality of the network is balanced and future periodic rehabilitations across the network do not occur at about the same time.

[28] This is an approximate concept only. It could take a very long time to reach such a steady state; for instance, Wellingtonians still benefit from the long-life pavements laid on the Wellington motorway in the 1960s. Furthermore, land use developments along major corridors and a long-term lack of corridor protection measures preclude attainment of a first best network. The 'legacy' of the investment regimes of the last 40 years will thus always have a major influence on future developments.

Once this steady state occurs, the average annual cost to maintain and operate the network may be less, even though the periodic rehabilitation cost may be greater.

Whether relatively high BCRs for such works can be sustained indefinitely is uncertain. The demand for costly construction projects driven by their major long-term benefits, such as major corridor improvements, may ease over time as the corridors are upgraded to a standard fit for the needs and purposes of current and future users. However, achieving this would probably require realistic travel options to be presented to motorists, particularly public transport services, so that initiatives for managing travel demand such as congestion charging may be made a viable alternative to further major capital works. This would reduce the case for sustained capacity expansion, and lower BCRs would result if these alternatives were included in CBA methodologies.

14.2.2 Brief assessment of current network quality and durability

New Zealand has one of the most maintenance-intensive road transport networks in the developed world. A high proportion of the NLTP is spent on maintenance, with 45% of the NLTP being spent, on average, on maintenance between 1991 and 2006 (Hyder 2008). While the cause of the high maintenance burden is not entirely clear, the quality and robustness of the network is a likely key contributor. For instance, 65% of New Zealand's road network is sealed, mostly with a thin chipseal over a crushed gravel base, and 'many of our current pavement construction projects are in a wet environment, which has not been considered in the [pavement] modelling nor design analysis,' (Hutchison 2006) and often struggles to meet its designed life cycle of 25 years.

14.2.3 Long-term effects of enhancing quality

The outcomes from a higher quality and more durable network will be economic assets with longer lives, lower total cost of ownership, less disruption to network users resulting from maintenance activities, less risk of asset failure and higher standards of service provision (eg reduced vehicle operating costs and noise impacts from smoother, quieter pavement surfaces). In essence, the network would be more sustainable.

While many of these outcomes will accrue over the life of the higher quality asset, the bulk of the outcomes are cost savings that occur when the base case infrastructure would have been substantially upgraded, usually at about 25 years of age. The cost savings can be realised either by reducing charges to road users and taxpayers, or by investing those savings in additional infrastructure, with the latter being more likely if the future cut-off BCR is high at the time the savings are incurred.

14.2.4 The legacy of using a 10% discount rate

In considering the effect of lowering the discount rate, as well as the extent of any reduction in the discount rate, the other main factor is the length of time the discount rate was sustained at the previous value. A 10% discount rate has been used in New Zealand since the 1970s. Lowering the rate from, say, 10% to 4% would have quite different effects if the discount rate had always been 4%.

The main influence on this would be the *extent of preclusion* of those types of initiatives that were suppressed under a high discount rate but would be prioritised under the lower. For argument's sake, if all initiatives that were evaluated and then rejected were precluded from ever being undertaken in any shape or form, then the legacy of the previous discount rate would be greatly reduced. The number and nature of projects of each type evaluated each year may, in that case, be fairly independent of previous decisions, and the network could swiftly transition to a new steady state.

On the other hand, most maintenance-related initiatives and major capital works that may have been rejected in favour of maintaining the status quo or some other modest investment could still be undertaken at a later date in a standard or configuration not too dissimilar to that originally envisaged. Long-life pavements could be laid when the existing pavement is rehabilitated, and unless extensive land use developments have occurred, many major capital works may still be relatively viable. While more costly mitigation features would probably be needed on deferred major capital works, particularly urban motorways, the projects themselves or similar substitutes will probably still be economically viable.

The greater the degree of suppressed investment in such works, the greater the effect of lowering the discount rate, and the longer it would take to transition to a new steady state for a given budget over time. Given the use of one of the developed world's highest discount rates for four decades, and the lack of significant development on New Zealand's most essential routes (Ministry of Transport 2009), it is likely that any significant lowering of the discount rate would lead to strong pressures to alter the mix of investments undertaken for a sustained period of time, perhaps several decades, before all such suppressed investment is released and a new steady-state investment pattern can take effect.

14.3 Transitioning towards a higher quality, more durable network

14.3.1 Issues

Planners would be under strong instantaneous pressure to undertake initiatives that improve the quality and durability of existing infrastructure following a significant reduction in the discount rate. Not only would projects have much higher BCRs, but many would have a lower total cost of ownership, making them new 'do-minimum' approaches. The current funding allocation framework has previously prioritised such 'do-minimum' works over all else. Under the existing BCR formulation, these projects would have much smaller denominators (as total PV costs are much smaller), making the BCRs highly responsive.

A key issue for authorities would be to maintain a suitable balance between undertaking works to enhance quality and durability, and continuing to undertake a programme of new investments necessary to achieve short-, medium- and long-term government strategy targets. It is not sustainable to undertake too much investment in works that enhance quality and durability at the expense of the existing programme and the needs of transport users now and in the short term. In the absence of effective management of the transition phase, an unsustainable outcome is indeed possible. In that case, something would have to give, and it would most likely be the influence of CBA in the funding allocation framework.

14.3.2 Taking heed of CBA

While an economic purist may argue that once the discount rate has been set, the CBA results should be adhered to, some caution may be warranted. The issue is that if the discount rate was suddenly lowered to represent an STPR and was set at, say, 4%, leading to CBAs that recommend substantially different investments, then it begs the question whether CBAs have been wrong for the last 40 years. After all, such a change in the public sector discount rate would not reflect a sudden change in society's underlying value of time; rather, it would only be an alteration of economists' and policy advisors' understanding and application of the issue.

If the discount rate changes modestly but the paradigm that governs the discount rate remains then the altered CBA results should continue to be just as strongly adhered to. Examples are a changing asset beta or an effective marginal tax rate within the SOC, or a change in the expected future growth rate in the STPR; it was argued earlier in section 5.2 that it was the lowering of the effective tax rate that led to Treasury reducing the discount rate from 10% from 8%.

However, if the paradigm that is judged to govern the public sector discount rate itself changes, then the credibility of CBA could be questioned. If the discount rate is correct now, does this imply that it was wrong then (or vice versa)? Either way, many would take some convincing to adhere strongly to a substantially different CBA recommendation, unless these people have a strong belief that some possible altered discount rate was the correct one. If many agree that the revised discount rate was the right value to use, then the CBA recommendations would probably guide the most appropriate investment pattern over time to maximise social wellbeing over the short, medium and long terms.

However, the extent to which CBA is judged to capture wider economic, social and environmental effects will remain the most important consideration. A lower discount rate could reveal more effects that have been omitted from current CBA methodologies, such as the value of CO_2, crash costs, and other environmental and social effects, which may offset any move towards a greater influence of CBA in decisions.

14.3.3 Managing the medium-term effects of substantially lowering the discount rate

14.3.3.1 Possible measures

Measures that are compatible with economic CBA methodologies to manage the transition include:

- updating CBA methodologies so they are better at measuring and assessing those effects not deemed to be captured in CBAs (for instance, wider economic benefits, environmental sustainability, improving access and mobility, and public health impacts) – these should be undertaken anyway, but the need to do so is enhanced at a lower discount rate
- temporarily expanding the budget from central government sources to partly mitigate the excess demand for funds (through increased taxation, borrowing or reprioritising)
- increasing funding from other sources such as tolls and debt financing
- developing an economic and policy framework that applies a leveraged BCR formula which increases the priority of initiatives when funds with a lower opportunity cost are offered from outside the NLTF.

Measures to manage the transition that deviate from pure economic CBA recommendations but do not totally discard CBA techniques include:

- developing an adjusted CBA framework (in addition to the existing CBA framework) that alters the significance of certain effects, such as:
  - requiring selected kinds of maintenance initiatives to underplay future cost-saving effects
  - prioritising upgrades of key corridors over other network components

- factoring up the impact of initiatives that are disadvantaged by the lower discount rate (e.g. raising the value of travel time savings, and/or applying a proxy value to public transport initiatives for strategic option values from having substitute modes)
- using a different discount rate for different initiatives

- separating certain activity classes unfavourably affected by a lower discount rate and allow them to have lower average BCRs, and use BCRs for prioritising within those activity classes.

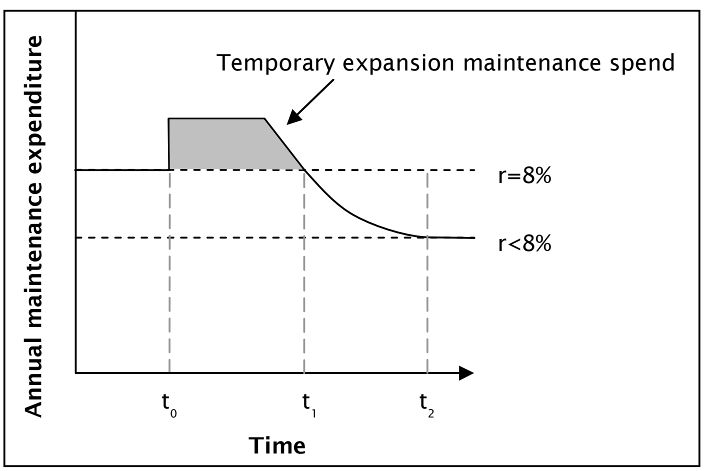
The third class of measures is simply to reduce the emphasis of CBA for certain types of investment activity and significantly increase the use of multi-criteria analysis.

14.3.3.2 Temporarily expanding the budget

A temporary expansion of the budget is the primary approach for managing a transition between steady states. Works to enhance quality and durability are non-excludable, precluding tolling and private equity and debt, leaving the primary method of expanding the budget being increased taxation and public debt.

The dynamic path from a significant lowering of the discount rate is sketched in figure 14.1. The steady-state cost to maintain and operate the network will be less under a lower discount rate. Following a reduction (at t_0), the dynamically optimal transition towards the new steady state involves a temporary expansion over and above the existing steady-state level of expenditure. As the network progressively meets the desired standard, the excess demand for works that enhance quality and durability would ease, moderating BCRs and marginal BCRs, and allowing maintenance and operating expenditure to settle at the new steady state.

Figure 14.1 Indicative ideal dynamic path towards a lower discount rate steady state



Between periods t_0 and t_1 in figure 14.1, the investment programme would be in catch-up mode. Between periods t_1 and t_2, the primary effects of reducing costs would be felt progressively, and marginal BCRs would lower. The greater the reduction in the discount rate, the more intense the temporary expansion and the lower the annual maintenance expenditure (depending on available technologies).

The NZTA's existing economic procedures could be improved to consider the economic impact of third party revenues further in their many varied forms. No guidance is currently provided for:

- appraising resource contributions from sources that may be somewhat constrained, but less so than the transport sector budget (such as other public sector entities)
- private sector contributions which are not tolls or fares but which come from unconstrained sources, such as developer contributions
- appraising the tolling of projects that otherwise *would* happen in order to ease the budget constraint and to allow other projects to occur (the 'BCR of leveraging' as outlined in section 2.18.3 of ATC (2006a and 2006b)).

The final point needs to be complemented by improvements to policies and legislation.

14.3.3.3 Deploy an adjusted CBA framework in addition to the existing CBA framework

Measures could be taken to manage the effects of a substantial reduction in the public sector discount rate that deviate from pure economic CBA recommendations but do not totally discard CBA techniques. A suggested approach is that recommended by the Australian Transport Council (2006b), summarised below.

According to this approach, adjusted CBA is a more formal and transparent way of ranking initiatives according to predetermined weights for objectives, particularly non-efficiency objectives. It is a hybrid of multi-criteria analysis and CBA that retains the dollar measurement of CBA.

The actual prioritisation of initiatives involves subjective consideration of all relevant factors using multi-criteria analysis; CBA is only one relevant factor of this, albeit an important one.

CBA might be considered too narrow to be the sole basis for prioritising investment initiatives for three reasons:

- CBA values benefits and costs on the basis of preferences of individuals (willingness to pay), which the government may, in some cases, regard as inappropriate.
- CBA omits certain effects because they cannot be expressed in monetary terms.
- CBA ignores social equity, as it takes no account of how the benefits and costs are distributed among members of society.

Adjusted CBA can be undertaken by modifying the standard CBAs by:

- replacing values for certain parameters with nominated values
- multiplying specified benefits or costs by a weighting factor (>1 to give greater weight and <1 for less weight)
- inserting subjectively determined monetary values for particular non-monetised benefits or costs
- weighting the distributional impacts across society differently depending on who they accrue to.

> *The main argument against adjusted CBA is that it 'distorts' the results of CBAs in such a way that it can give less economically efficient initiatives precedence over more efficient initiatives. It could lead to some highly wasteful initiatives being implemented. However, this is the desired result if it reflects government directions. As a safeguard, adjusted CBA results should never be reported separately from the corresponding unadjusted CBA. This ensures that the potential efficiency losses from decisions based on adjusted CBA results are transparent.* (ATC 2006b)

Adjusted CBA could be used to prioritise works that enhance quality and durability on key corridors over other network components. This may be necessary if the budget did not expand sufficiently to accommodate the upgrades and the existing programme sustainably. A quality and durability upgrade would have the greatest impact on the most highly trafficked network components. Alternatively, works to enhance quality and durability could be made to use a lower value of the future cut-off BCR (assuming they use the NBIR specification of the BCR) to downplay the effect of cost savings in the future.

14.3.4 Summary

The extent to which investors and planners adhere to the altered CBA recommendations resulting from any significant lowering of the discount rate is perhaps most influenced by how strongly stakeholders believe in the appropriateness of the updated discount rate. If any major reduction was deemed appropriate by all, then CBA would probably have a greater influence in decisions than it currently does, moderating the role of multi-criteria analysis, and simplifying transport planning and strategy development. The extent to which CBA is judged to capture wider economic, social and environmental effects will remain the most important consideration, however.

14.4 Revisiting strategic transport priorities

A material lowering of the discount rate may lead to investments that do not naturally align themselves with achieving the NZTS's targets for 2040[29] (Ministry of Transport 2008), particularly those relating to public transport and active modes. While a lower discount rate may improve the priority given to Roads of National Significance[30], the increased priority given to maintenance initiatives from a lower discount rate could crowd restrict funding available for Roads of National Significance projects (as well as increasing the initial investment cost of these projects because their BCRs are higher if they have lower whole-of-life costs).

While some effects may not align with strategic policy objectives, alternative 'stretch targets' can be devised so that outcomes that do align with strategic policy objectives are given an advantage by the lower discount rate. Some examples of specific targets that could be developed include:

- lower whole-of-life costs
- a reduction in the failure of infrastructure assets
- a reduction in disruption to network users caused by maintenance activities
- a reduction in average noise levels of key routes
- a reduction in the amount of oil-based products used to maintain the network.

[29] Examples of targets in the NZTS (Ministry of Transport 2008) are:

- increasing use of public transport to 7% of all trips by 2040 (ie from 111 million boardings in 2006/7 to more than 525 million boardings in 2040).
- Increasing walking, cycling and other active modes to 30% of total trips in urban areas by 2040.

[30] These Roads of National Significance are described in the 2009 *Government policy statement on land transport funding* (Ministry of Transport 2009).

15 Conclusions and recommendations

15.1 Overview

The recommendations are summarised below and expanded upon further in the rest of this chapter.

Firstly, we recommend that the following actions be taken regardless of any treatment of the discount rate:

- extending the baseline appraisal periods for large projects to the extent that is supported by formal modelling
- issuing guidance on the 'rolling over' method for mutually exclusive initiatives with lives that differ in length
- altering the BCR formula to the NBIR formula, which includes centrally prescribed assumptions of the future cut-off BCR
- improving guidance for appraising maintenance strategies to capture how road users and externalities will be affected while the NBIR is in use
- improving the valuation of third party revenues with lower opportunity costs than NLTF resources (leveraged BCR formulae)
- improving knowledge acquisition by voluntarily uploading CBA data from EEM software for research purposes.

Other actions are advised, as they recognise the need to test the sensitivity of the CBA results to the choice of discount rate and to determine the best estimate of present value benefits and costs incurred under different discount rate scenarios:

- undertaking sensitivity testing of the discount rate
- developing approaches to extend appraisal periods credibly past what is currently supported by formal modelling
- improving questionable CBA assumptions that are masked by the current high discount rate and thus support meaningful sensitivity testing of the discount rate
- considering – and, if needed, improving guidance on – how parameter values may change if the social discount rate were tested for sensitivity.

A third class of actions are advised to alter the value of the discount rate and ensure that the transport system responds appropriately:

- agreeing on a framework for basing the public sector discount rate upon the STPR, or some combination of the STPR and the SOC
- issuing guidance regarding the shadow pricing of private sector impacts, where necessary
- reviewing governance processes to ensure that a lower discount rate will not lead to undue crowding out of private sector transport initiatives

- reviewing policies and legislation to determine options for obtaining sustained increases in funds to the land transport sector
- revisiting strategic transport objectives to develop alternative 'stretch targets' advantaged by a lower discount rate
- reviewing strategic transport policy and evaluation frameworks to ensure that the transition towards a new system equilibrium is managed appropriately
- adjusting CBA methodologies in order to maintain or improve the influence of CBA by ensuring that the methodologies capture the 'softer' impacts that are not properly accounted for at present.

We advise that the first two sets of actions should be undertaken regardless of any consideration of the default or baseline discount rate.

15.2 Recommendations regardless of the baseline discount rate or sensitivity assessments

- **Extend baseline appraisal periods for large projects to the extent it is supported by formal modelling**

The analysis indicated that even at the (then) prevailing 10% discount rate, the present value of benefits could be materially increased if the appraisal period were extended. This is probably also true of the current 8% discount rate.

Irrespective of the discount rate or transport CBA, it is important for transport planners to consider the longer term (>30 years) if they are able to do so, and they should not be discouraged from it by prescribed CBA procedures.

If the formal modelling of impacts after 30 years is not deemed to be viable by New Zealand transport professionals, as is the case in the UK, then the current prescription does not need to be changed.

- **Issue guidance on the rolling over method for mutually exclusive initiatives with different length lives**

The EEM should provide explicit advice on the rolling over method described in this report to compare mutually exclusive initiatives with lives of different lengths. Initiatives currently deemed to be broadly economically inefficient, such as structural asphalt, perhaps, could actually be efficient if they were appraised properly.

An annuity-equivalent method should be avoided or at best only reluctantly advised, because the rolled over cashflow profiles of most initiatives will not be exact duplications of the original cashflows (identical cashflow profiles are a requirement for the two approaches to be equivalent). Reasons why the rolling over method is preferred include rising real input costs and that subsequent treatments (particularly structural asphalt) may require only modest upgrades at the end of the projects' lives (and some pavement treatments may not even have well-defined lives anymore).

- **Alter the BCR formula to the NBIR formula that includes centrally prescribed assumptions of the future marginal or cut-off BCR**

The BCR review in chapter 11 recommends the BCR formula be altered to the comprehensive NBIR formula as it is called in this report (equation 11.3). This requires operating and maintenance costs to be multiplied by an assumed future long-term cut-off BCR – the factor by which operating costs are multiplied to reflect the opportunity cost of funds in the future – and subtracted from the present value benefit calculation.

This is important to allow a consistent comparison of maintenance-oriented initiatives, which consume a large proportion of available funds, with other initiatives, and allow an informed basis to trade CBA results off against non-CBA factors in a multi-criteria investment framework. Currently, this cannot be done, as the existing BCRs can be totally misleading as a measure of the extent of economic efficiency for initiatives with significant future cost/cost-saving components.

- **Improve guidance for appraising maintenance strategies to capture impacts to road users and externalities, whilst using the NBIR**

The investment criterion of automatically choosing the lowest NPV cost option for maintenance should be discarded and replaced with the NBIR criterion. Projects with the lowest NPV-cost will still be chosen if no benefits result and if the cut-off BCR is appropriately specified.

This approach will encourage consideration of wider impacts such as the effects of fewer maintenance disruptions and lower noise levels on road users and the wider community, and a reduced risk of pavement failure.

This approach would provide appropriate and needed guidance on how to incorporate such impacts into the appraisal.

- **Improve the valuation of third party revenues with a lower opportunity cost than NLTF resources (leveraged BCR formulae)**

The level of guidance in the EEM for appraising third party revenues requires improvement. No guidance is currently provided for:

- appraising resource contributions from sources that may be somewhat constrained, but less so than the transport sector budget
- private sector contributions which are not tolls or fares but which come from unconstrained sources, such as developer contributions
- appraising the tolling of projects that otherwise *would* happen in order to ease the budget constraint and to allow other projects to occur.

The final point needs to be complemented by improvements to policies and legislation.

- **Improve knowledge acquisition by voluntary uploading CBA data from EEM software for research purposes**

In order to understand the impact of certain economic procedures and parameter values, we must have knowledge of the CBA appraisals of both implemented initiatives and initiatives that were not implemented but could have been if the change were to occur.

This research pulled the key data inputs of over 160 CBAs and devised methods to populate the overall appraisals automatically for each classification of project. Transport CBAs themselves require only a very small package of input data and the subsequent appraisal is essentially process driven. In many cases, this data already exists and is almost available to the NZTA because appraisers input them into the NZTA's

EEM software[31]. However, instead of uploading this small data package, the software merely produces PDFs, which are then uploaded.

An option should be provided to allow approved organisations to submit that small package of CBA data electronically to the NZTA for research purposes, and it would not take any human resources at their end. The issues to manage may relate to the IT systems required and perceptions of what the NZTA may do with that data.

15.3 Recommendations regarding sensitivity assessments

- **Undertake sensitivity testing of the discount rate**

This research has highlighted the contention and uncertainties relating to the choice of discount rate, and it is therefore very important that sensitivity assessments of this variable are undertaken to inform decision makers.

The EEM should provide guidance on how to do this in a consistent way across all projects.

- **Develop approaches to extend appraisal periods credibly past that which is supported by formal modelling**

In most cases, long-term forecasting can only be achieved by extrapolation and assumption; formal modelling and detailed analysis are unlikely to be feasible or worthwhile. However, transport authorities worldwide do not seem to have a good understanding of how to conceive of such long-term effects theoretically and they issue rule-of-thumb guidance only.

Nevertheless, sensitivity testing of the discount rate will make impacts in the long term (>30 years) material to the appraisal. The NZTA needs to issue guidance on how to treat this appropriately in order for all projects to be comparable.

- **Improve questionable CBA assumptions masked by the current high discount rate to support meaningful sensitivity testing of the discount rate**

Many simplifying assumptions are made in current CBAs and some of these may not be appropriate in a lower discount rate environment. However, irrespective of whether the baseline discount rate is lowered, they are perhaps not even appropriate if much lower discount rates were applied in a ‘what if’ sensitivity assessment of the discount rate.

Possible questionable assumptions include:

- an aversion to forecasting changing land-use patterns as a result of any transport initiative or strategy
- a reluctance to model induced travel for major projects that may generate additional economic activity and change the propensity to travel
- constant linear growth rates of trips over time
- no relative price effects for costs or benefits over time (the NZTA is funding research on this currently)

[31] For instance, visit www.landtransport.govt.nz/funding/eem-software/index.html

- low emphasis on valuing real options, particularly for mutually exclusive initiatives with lives of differing length
- no change in automotive technologies (eg the widespread introduction of electric vehicles).
- **Considering – and, if needed, improving guidance on – how parameter values may change if the social discount rate were tested for sensitivity**

The basis for some unit cost values may be implicitly based on the discount rate, such as the cost of carbon, the cost of crashes, and other health and environmental impacts that do not represent only immediate effects. If a significantly lower discount rate was applied to an appraisal, the unit cost values of such impacts should also be adjusted for consistency. However, this study has not considered how they may be affected.

15.4 Recommendations regarding lowering the discount rate

- **Agree on a framework for basing the public sector discount rate upon the STPR, or some combination of the STPR**

The Treasury permits sectors to use a sector-specific discount rate. Transport officials should seek to determine how that should be specified. The decision should bear in mind that the necessary normative judgements required in the STPR should ultimately not be governed by someone acting in their professional capacity as an economist but someone acting as a policy maker.

This research has highlighted many concerns about the derivation of the current SOC discount rate and how this rate is applied, irrespective of how it is determined. Several theoretical reasons suggest why an STPR should be used, and an STPR approach is now generally being implemented by nations that are higher in the OECD rankings than New Zealand is.

A discount rate in the order of 3–5% would probably be appropriate on economic grounds, but it is important that Ministry of Transport officials have a major influence on the final value prescribed.

- **Issue guidance regarding the impact of shadow pricing private sector impacts where necessary**

In certain circumstances, the use of a SOC discount rate is convenient for CBA appraisers when considering the present value of impacts to firms and private sector investment contributions. Further guidance would be necessary on how to assess those impacts if a consumption (STPR) discount rate is used. For example, should this potential complication be ignored or should shadow pricing be applied, or should a different social discount rate be applied? If the latter, should these impacts be discounted using the SOC rate or perhaps a weighted average of the SOC and STPR instead?

- **Review governance processes to ensure that a lower discount rate will not lead to undue crowding out of private sector transport-related initiatives**

This paper argues that concerns about specific NLTF-funded activities crowding out specific private sector initiatives can best be managed by good governance processes and informed use of CBA by the NZTA and approved organisations rather than wholesale lifting of the discount rate.

If a much lower discount rate is actively being considered, it is probably necessary to formally assess the merits of this claim, and review the appropriateness of existing governance processes and policies.

- **Review policies and legislation to determine options for obtaining sustained increases in funds to the land transport sector**

Depending on the influence of CBA in investments, a much lower discount rate would place enormous pressure on the existing budget and on the need to expand the budget substantially in a sustainable way. This would probably require ground-breaking ideas on how to achieve this.

For example, currently tolling legislation, policies and CBA methodologies are only geared for making a project happen when it otherwise would not. These should be changed during the current Land Transport Management Act review to encourage the tolling of projects that otherwise would happen in order to ease the budget constraint to allow other projects to occur. A strong economic rationale supports this, but it is poorly understood across all levels of the New Zealand transport sector.

- **Revisit strategic transport objectives to develop alternative stretch targets advantaged by a lower discount rate**

A material lowering of the discount rate may lead to investments that do not naturally align themselves with achieving the NZTS (Ministry of Transport 2008) targets for 2040, particularly those relating to public transport and active modes. While some effects may not align with strategic policy objectives, alternative 'stretch targets' can be devised so that outcomes that do align with strategic policy objectives are advantaged by the lower discount rate. Specific targets could be developed relating to initiatives that lower whole-of-life costs, reduce the failure of infrastructure assets, reduce disruption to network users caused by maintenance activities, reduce average noise levels of key routes and reduce the amount of oil-based products used to maintain the network, for example.

- **Review strategic transport policy and evaluation frameworks to ensure the transition towards a new system equilibrium is best managed**

Proactive management of a 'transition phase' following any major reduction of the discount rate would be required. The purpose would be to help investments and revenue strategies find an appropriate balance in the incidence of benefits and costs to different parties over time, investment in different transport modes and investment between regions.

The 'transition phase' is likely to be a major issue to manage, given the very long timeframe of 40-odd years that the 10% real discount rate has been applied for. It could take many decades to transition fully and for all resulting cost savings to be experienced, and this length of this transition phase will be longer if enough extra revenues do not come into the sector.

- **Adjust CBA methodologies in order to maintain or improve the influence of CBA, by ensuring that the methodologies capture the 'softer' impacts that are not properly accounted for at present**

CBA methodologies should be updated so they are better at measuring and assessing those effects that are not deemed to be captured in CBAs (for instance, wider economic benefits, environmental sustainability, improving access and mobility, and public health effects). These should be undertaken anyway, but the need to do so would be greater if a much lower discount rate was used.

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Appendix A: Benefits and costs of different project types

A1 Aims

Eleven project types have been evaluated in this research project. The time profiles of their benefit flows and benefit types are outlined in separate sections. The 11 project types are:

- motorway construction
- seal extension
- pavement smoothing
- rural safety alignment
- new and improved cycling networks
- safety improvement
- bridge renewal
- travel behaviour change
- preventative maintenance
- new and improved walking networks
- congestion improvement.

A2 Motorway construction projects

Figure A.1 Average time profiles of undiscounted benefits for two motorway construction projects

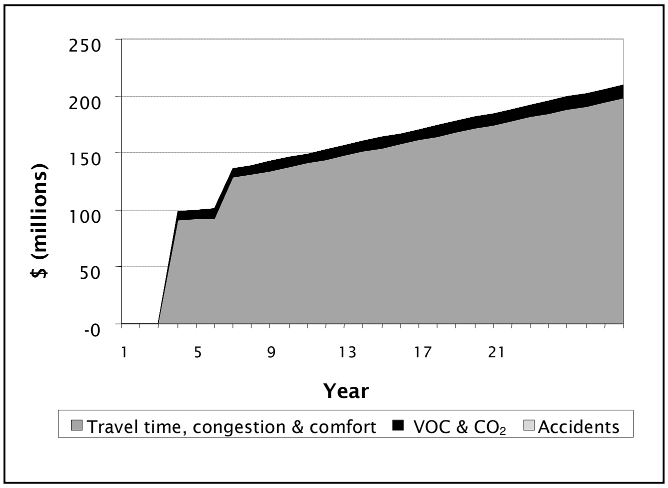
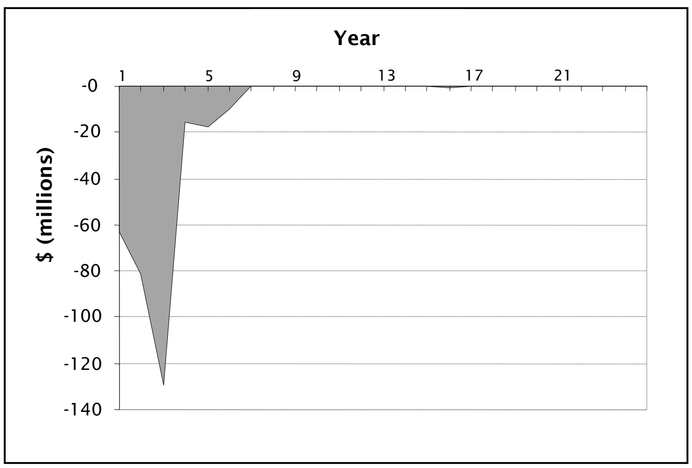


Figure A.2 Average time profiles of undiscounted costs for two motorway construction projects



The benefit streams of motorway construction projects (figure A.1) are characterised by a significant delay resulting from construction and are measured in the hundreds of millions of dollars annually. They are predominantly comprised of travel time savings and congestion savings, and have strong linear growth projections.

The cost streams (figure A.2) are large (average of $250m (PV) in investment costs) in the first few years with small ongoing costs to maintain the new infrastructure.

A3 Seal extension projects

Figure A.3 Average time profiles of undiscounted benefits for 50 seal extension projects

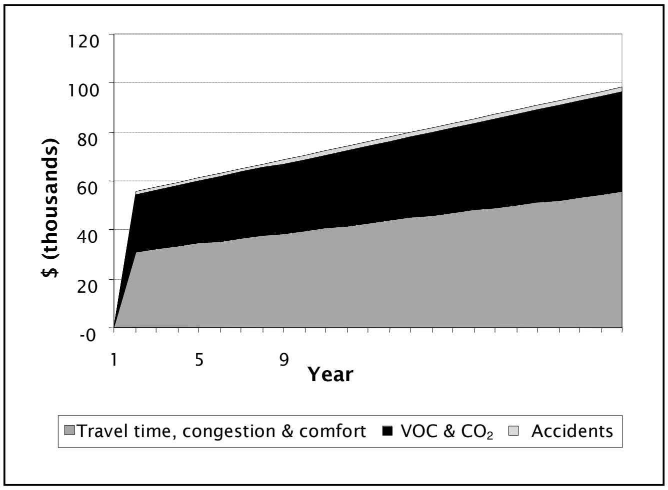
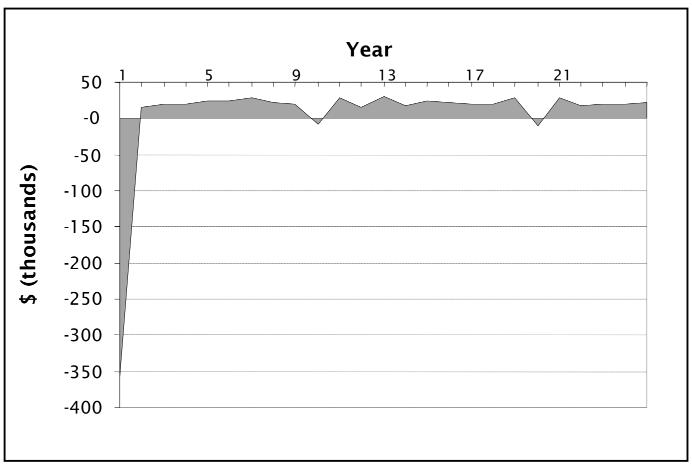


Figure A.4 Average time profiles of undiscounted costs for 50 seal extension projects



The benefit streams of seal extension (figure A.3) projects begin in the second year of operation and are made up of travel time savings (30%), comfort benefits (26%), vehicle operating costs including CO_2 (42%) and a small contingency for accident savings benefits (2%). The analysis is based on the simplified procedures whereby a single linear growth rate over the analysis period is judged to be sufficient.

Figure A.4 shows the costs incurred by seal extension projects. An initial cost of $350k is incurred on average in the first year but ongoing cost savings are made over the next 25 years thereafter, except for years 10 and 20, where periodic maintenance of the seal is undertaken. These cost savings are measured against a base case of continued maintenance grading and metal costs. The economic benefits of the base case compared to the do-nothing scenario are not evaluated because the do-nothing scenario is not a credible scenario and does not justify evaluation.

A dollar of cost saving is weighted more heavily than a dollar of 'benefit' in evaluations because of the binding nature of the government budget constraint.

A4 Pavement smoothing projects

Figure A.5 Average time profiles of undiscounted benefits for 37 pavement smoothing projects

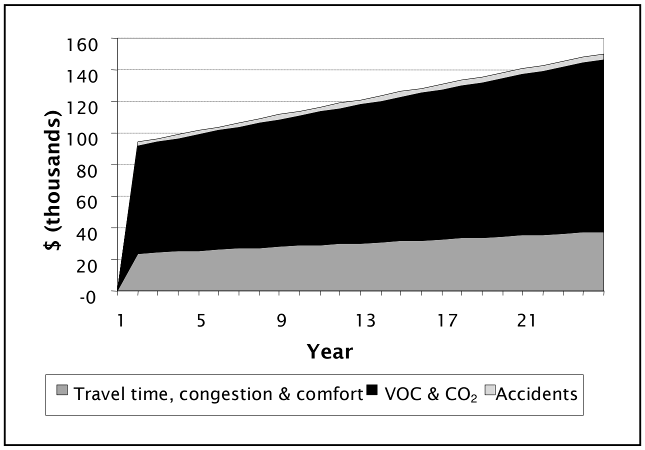
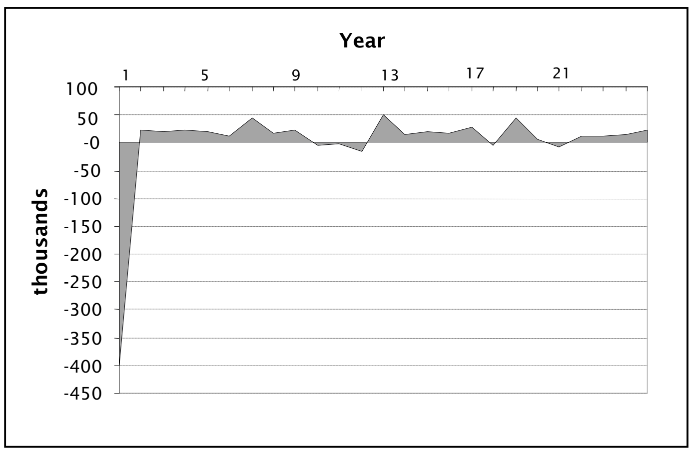


Figure A.6 Average time profiles of undiscounted benefits for 37 pavement smoothing projects



Pavement smoothing projects' benefit streams (figure A.5) begin in the second year of operation and are made up of travel time savings (25%), vehicle operating costs including CO_2 (72%) and accident savings benefits (3%). The analysis is based on the simplified procedures whereby a single linear growth rate over the analysis period is judged to be sufficient.

Figure A.6 shows the costs and savings associated with the pavement smoothing projects. An initial cost of $400k is incurred on average in the first year and ongoing cost savings over the next 25 years measured against a base case that involves frequent monitoring of pavement performance, and patches, reseals and heavy maintenance when roads show symptoms of shoving, rutting, edge breaking and flushing with reduced performance standards.

A dollar of cost savings is weighted more heavily than a dollar of 'benefit' in evaluations because of the binding nature of the government budget constraint.

A5 Rural safety realignment projects

Figure A.7 Average time profiles of undiscounted benefits for two rural realignment (safety) projects

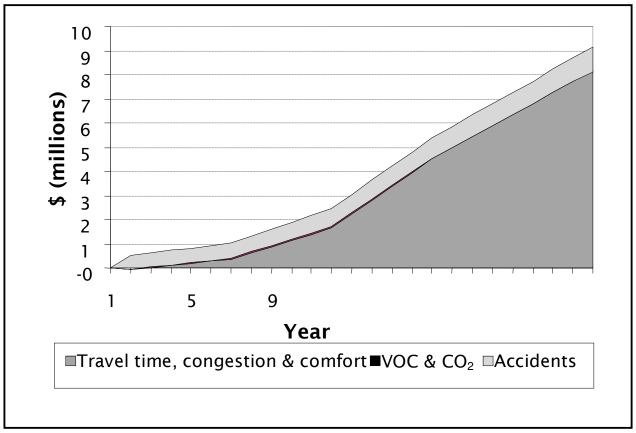
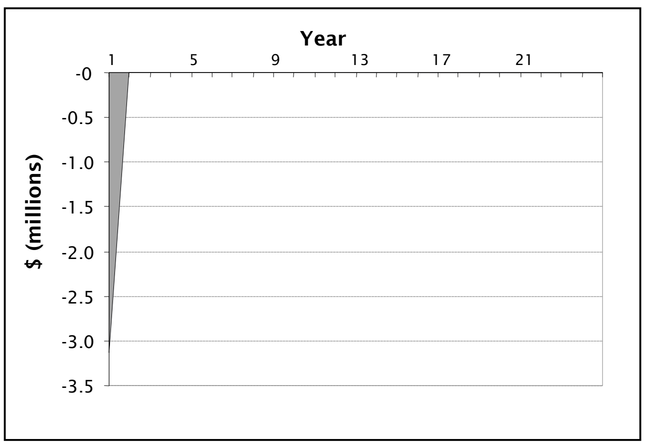


Figure A.8 Average time profiles of undiscounted costs for two rural realignment (safety) projects



The benefit streams (figure A.7) of rural safety realignment projects begin in the second year of operation and are made up of travel time savings (57%), vehicle operating costs including CO_2 (1%), congestion savings (12%) and accident savings benefits (30%). Travel time benefits are ramped up significantly and these projections are based on traffic modelling.

An initial cost of $3m is incurred on average in the first year followed by no change in costs relative to the base case (figure A.8).

A6 New and improved cycling networks

Figure A.9 Average time profiles of undiscounted benefits for 10 new and improved cycling network projects

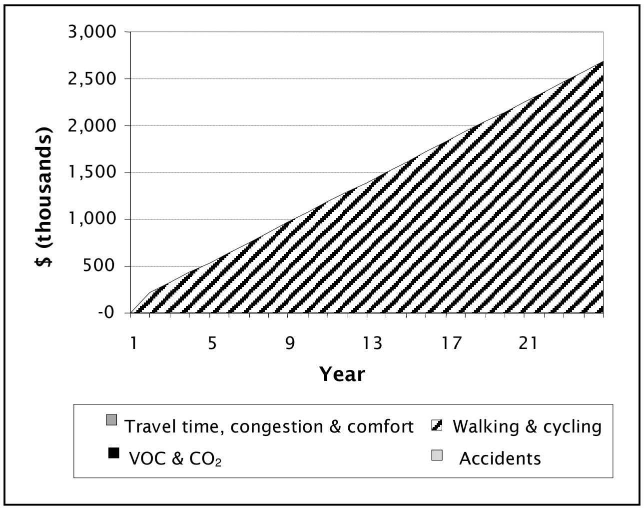
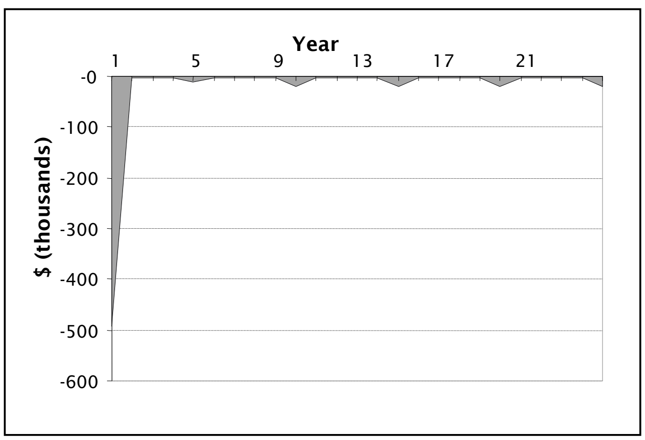


Figure A.10 Average time profiles of undiscounted costs for 10 new and improved cycling network projects



The benefit streams (figure A.9) of new and improved cycling network projects begin in the second year of operation and are made up only of walking and cycling benefits. The analysis is based on the simplified procedures whereby a single linear growth rate over the analysis period is judged sufficient.

An initial cost of $500k is incurred on average in the first year followed by five-yearly maintenance costs relative to the base case (figure A.10).

A7 Safety improvement projects

Figure A.11 Average time profiles of undiscounted benefits for nine safety improvement projects

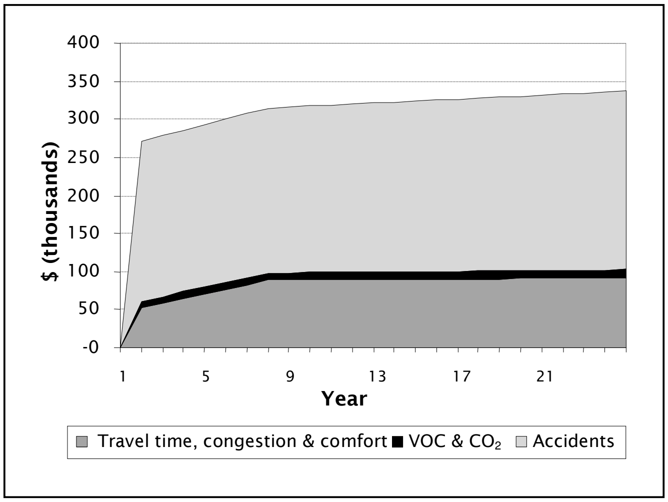
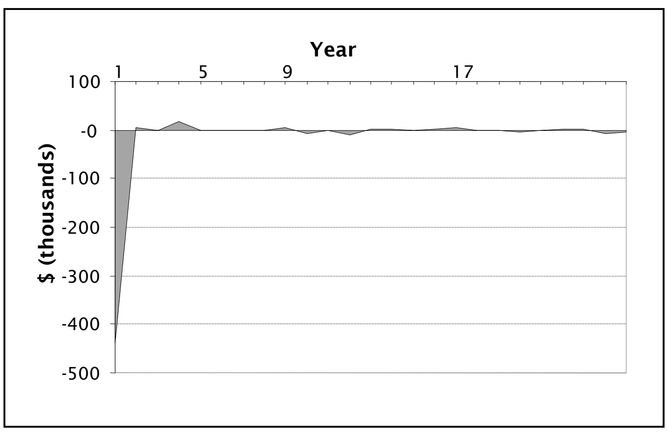


Figure A.12 Average time profiles of undiscounted costs for nine safety improvement projects



The benefit streams of safety improvement projects (figure A.11) begin in the second year of operation and are predominantly safety benefits (71%), with 26% travel time savings and 3% vehicle operating cost savings. The analysis of travel time and vehicle operating cost savings is based on a combination of traffic modelling and simplified procedures, with the former being used for larger projects. All accident benefits are single linear projections out from year 1.

An initial cost of about $400k is incurred on average in the first year followed by modest maintenance costs and maintenance cost savings over the analysis period relative to the base case (figure A.12).

A8 Bridge renewal projects

Figure A.13 Average time profiles of undiscounted benefits for four bridge renewal projects

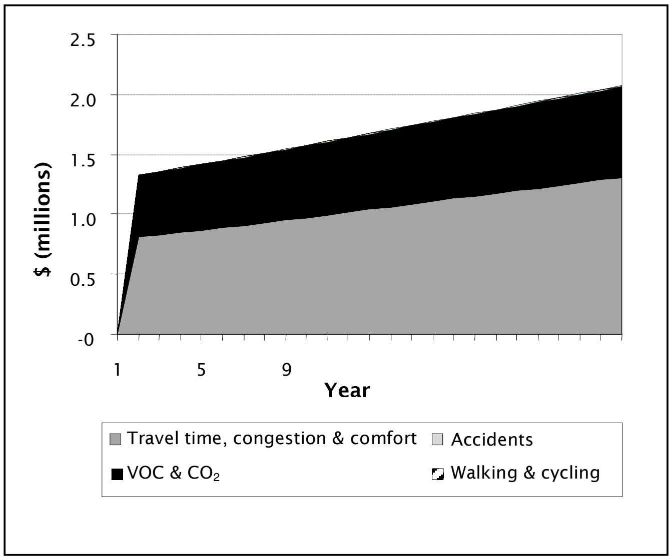
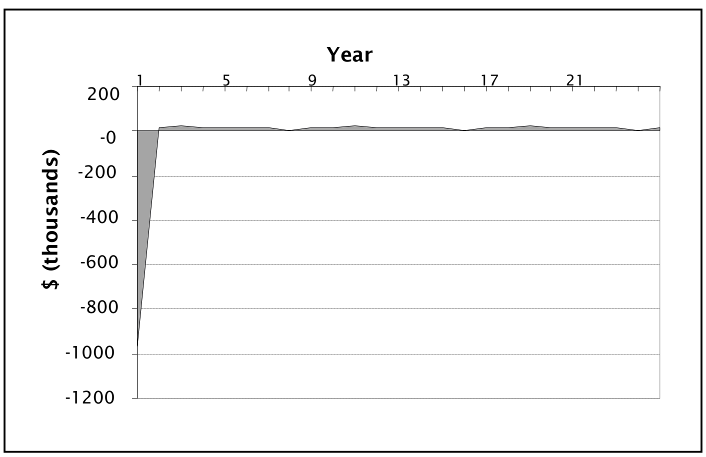


Figure A.14 Average time profiles of undiscounted costs for four bridge renewal projects



Bridge renewal projects are essentially route shortening projects. The benefit streams of bridge renewal projects (figure A.13) begin in the second year of operation and are made up of travel time benefits (59%), vehicle operating cost savings (38%) and congestion benefits (2%). The analysis of travel time and vehicle operating cost savings is based on a combination of traffic modelling and simplified procedures, with the former being used for larger projects.

An initial cost in the order of $1m is incurred in the first year followed by modest ongoing maintenance costs relative to the base case (figure A.14).

A9 Travel behaviour change projects

Figure A.15 Average time profiles of undiscounted benefits for eight travel behaviour change projects

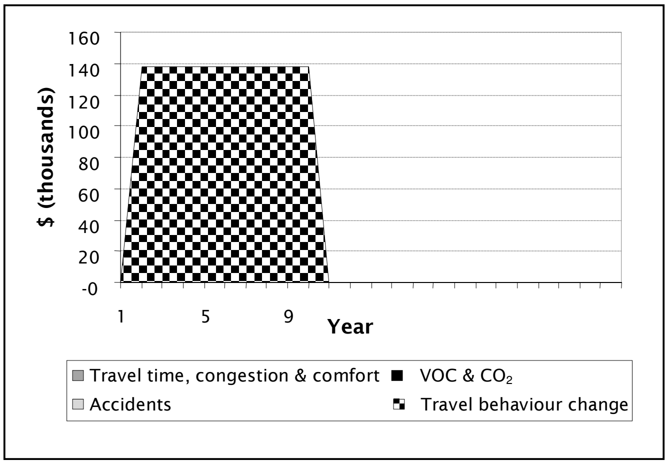
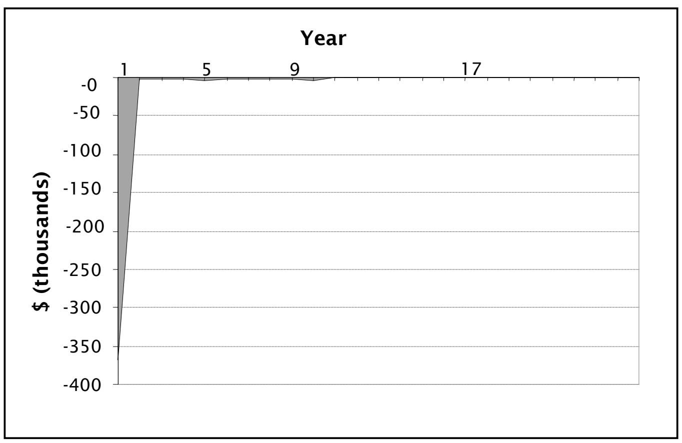


Figure A.16 Average time profiles of undiscounted costs for eight travel behaviour change projects

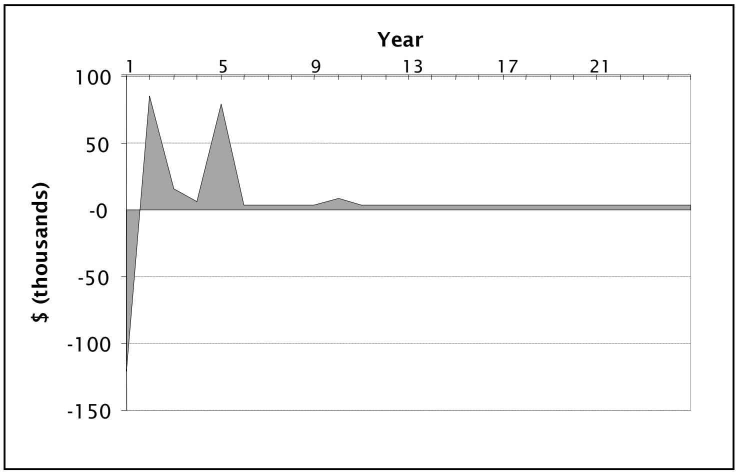


The benefit streams of travel behaviour projects (figure A.15) begin in the second year of operation and are assumed to last only 10 years. They are comprised solely of 'travel behaviour change' benefits that summarise all relevant benefit classifications. It is assumed that the benefit streams are uniform until the end of the analysis period.

An initial cost in the order of $350k is incurred in the first year followed by an average maintenance cost of $667 per year relative to the base case of doing nothing.

A10 Preventative maintenance projects

Figure A.17 Average time profiles of undiscounted costs for 21 preventive maintenance projects



Preventive maintenance projects do not have benefit streams as they are motivated by cost savings only. Generally, the evaluation tests an alternative maintenance approach against an incumbent approach to determine whether the discounted costs are lower. In effect, this is an evaluation to identify and confirm the 'do-minimum' approach.

Figure A.17 shows that an initial cost of $100k is incurred on average in the first year, followed by significant cost savings between years 2 and 5 and modest ongoing cost savings on average.

A11 New and improved walking networks

Figure A.18 Average time profiles of undiscounted benefits for five new and improved walking network projects

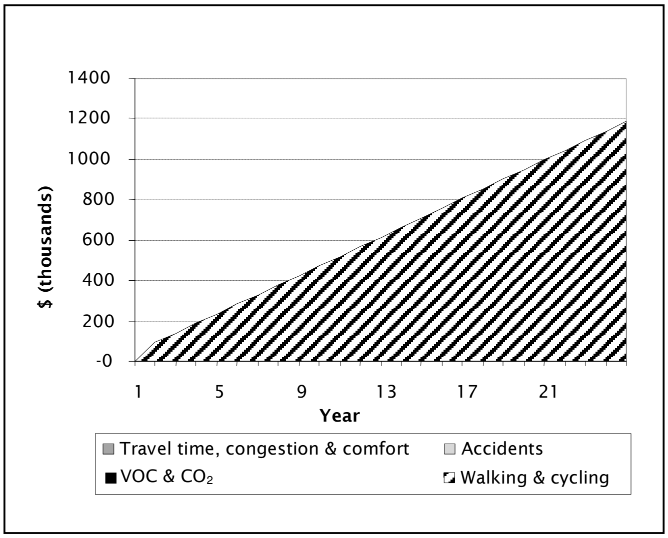


Figure A.19 Average time profiles of undiscounted costs for five new and improved walking network projects

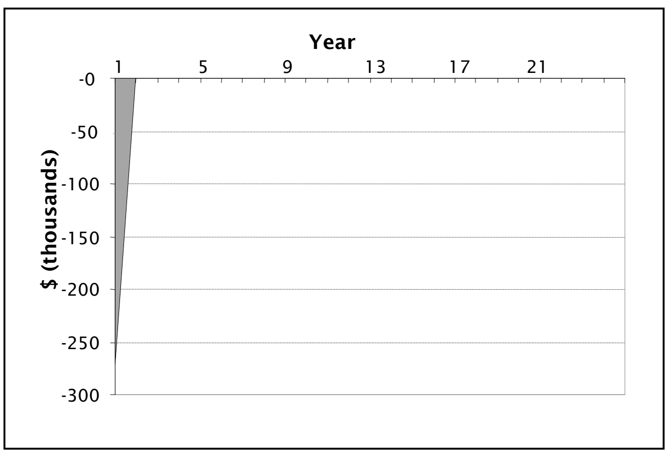


Figure A.18 shows that the benefit streams of new and improved walking network projects begin in the second year of operation and are made up only of walking and cycling benefits. The analysis is based on the simplified procedures whereby a single linear growth rate over the analysis period is judged to be sufficient.

An initial cost of $250k is incurred on average in the first year followed by yearly maintenance costs of $510 on average (figure A.19).

A12 Congestion improvement projects

Figure A.20 Average time profiles of undiscounted benefits for two congestion improvement projects

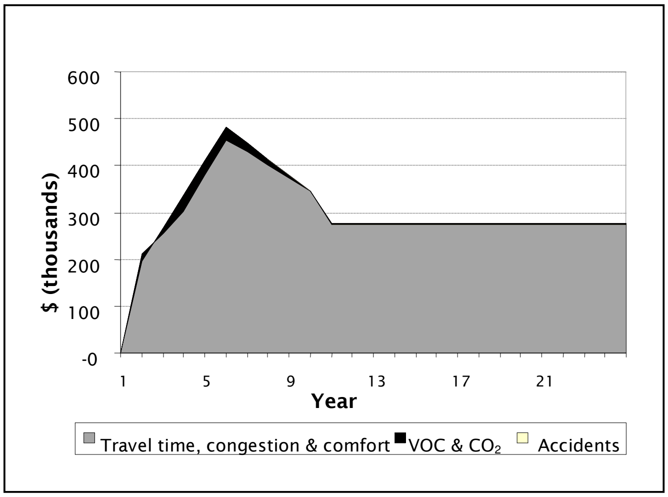
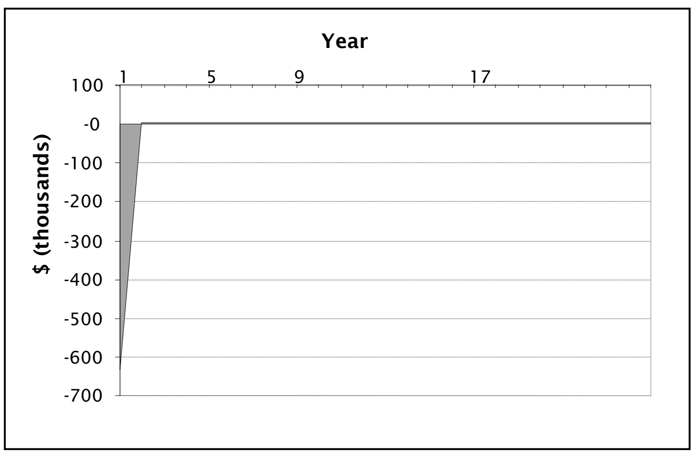


Figure A.21 Average time profiles of undiscounted costs for two congestion improvement projects



The benefit streams of congestion improvement projects (figure A.20) are based on traffic modelling, and begin in the second year of operation, grow strongly and then ease off to a steady state of $275k per year on average. They are predominantly travel time savings (89%), alongside congestion savings of 9% and vehicle operating cost savings of 3%.

An initial cost of $600k is incurred on average in the first year, followed by ongoing yearly costs of $2500 relative to the base case (figure A.21).

Appendix B Effect of discount rate reductions on BCRs

B1 General remarks

Motorway construction projects and seal extension projects were outlined in section 12.2.3 on page 84. The remaining project types are outlined below using the same assumptions as outlined in section 12.2.3.

Note that average BCRs and NPVs are simple averages rather than weighted averages. The symbol μ used in the figures represents the assumed future cut-off BCR.

B2 Pavement smoothing projects

Figure B.1 Effects on the BCR of pavement smoothing projects as the discount rate reduces

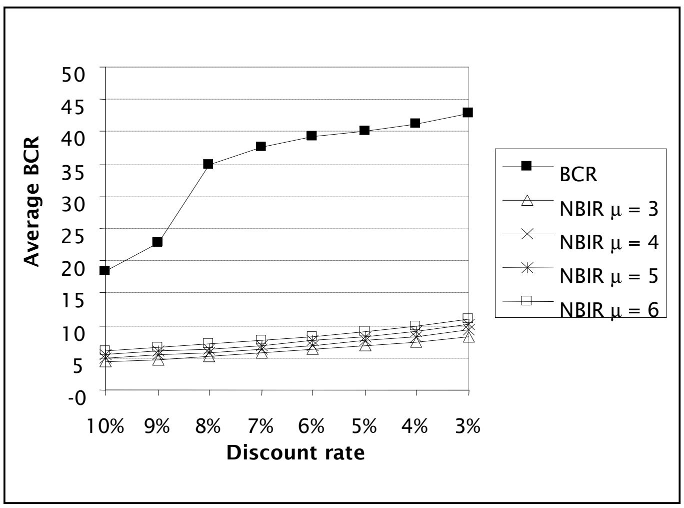
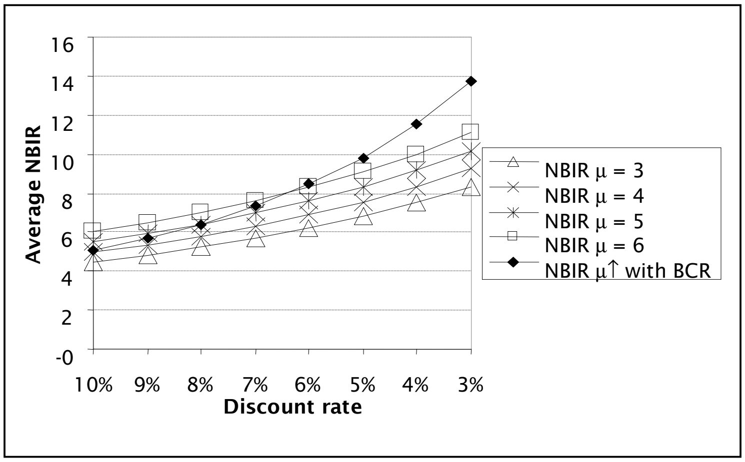


Figure B.2 Effects on the NBIR of pavement smoothing projects as the discount rate reduces



The effect of reducing the discount rate on pavement smoothing projects is much the same as for seal extensions, both of which are motivated by user benefits and cost savings. The existing BCR formula in the first graph in figure B.1 rises sharply as the discount rate is reduced because BCRs capped at 99 drag the average up as the discount rate is decreased.

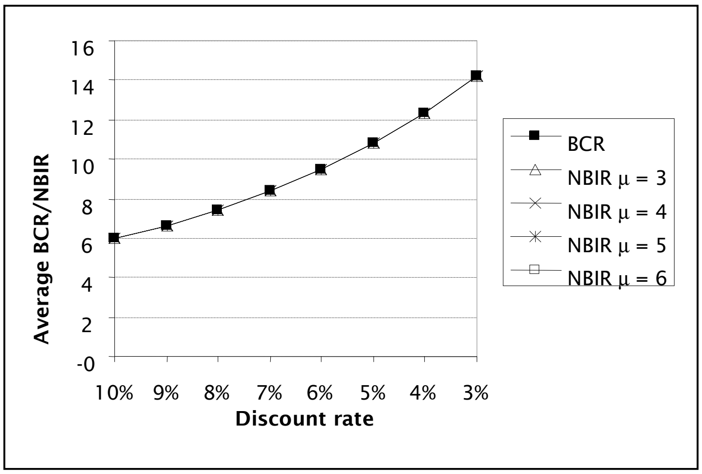
Again the NBIR is a useful substitute measure for aggregate comparison, and this is shown more clearly in figure B.2. Performance increases steadily:

- When the future cut-off BCR equals 4, the NBIR increases from 5.0 to 9.2.
- When the future cut-off BCR equals 6, the NBIR increases from 6.0 to 11 when $\mu = 6$.
- If the future cut-off BCR was to increase in line with table 12.2, the NBIR would increase from 5.0 to 14.

B3 Rural safety realignment projects

Neither of the two rural safety realignments obtained (figure B.3) included any maintenance or operating costs. This is presumably because any maintenance costs incurred are common to the option and its base case. As such, no difference can be seen between the standard BCR and the NBIR, and changing our assumptions about the future cut-off BCR has no effect.

Figure B.3 Effects on the BCR and NBIR of rural safety realignment projects as the discount rate reduces

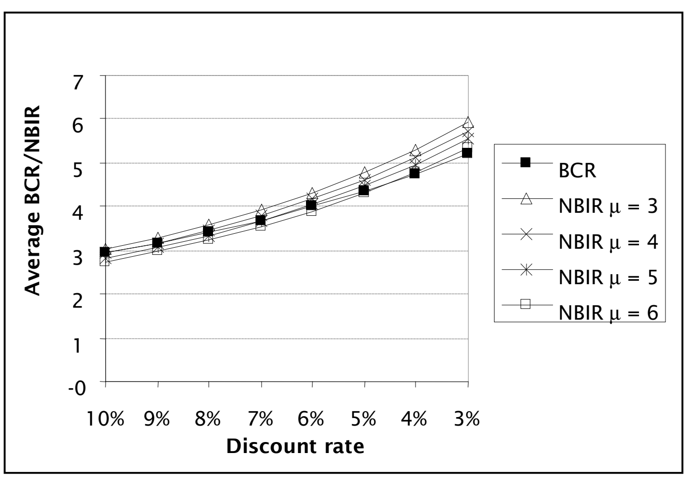


All BCRs for rural safety realignment projects increase from 6.0 to 14 (a 138% increase).

B4 New and improved cycling networks

The earlier discussion on time profiles of costs and benefits indicated that new and improved cycling networks undergo maintenance every five years. Figure B.4 shows a modest difference between BCR and NBIR performance depending on the assumed value of the future cut-off BCR.

Figure B.4 Effects on the BCR and NBIR of new and improved cycling networks projects as the discount rate reduces

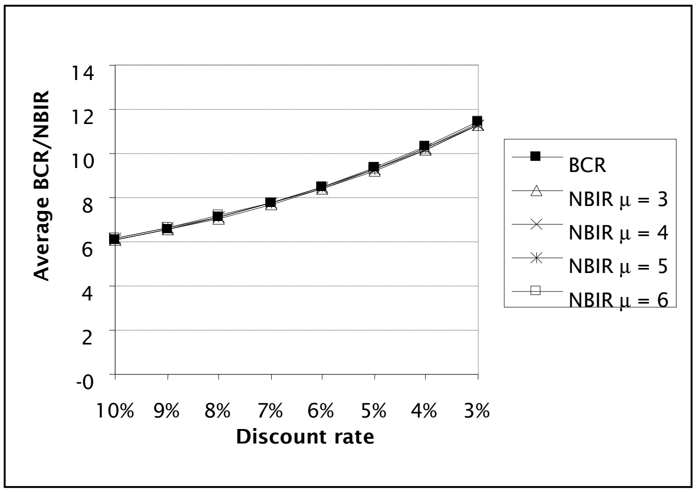


BCRs increase from 2.9 to 5.2 and NBIRs increase from 2.9 to 5.7 if $\mu = 4$, and increases from 2.9 to 4.8 if μ increases as the discount rate is lowered.

B5 Safety improvements

The nine safety improvement projects we obtained had small maintenance and operating costs after year one over and above their base cases (yearly average $2400). Little difference was found between the standard BCR and the NBIR, and changing assumptions about the future cut-off BCR had little effect (figure B.5).

Figure B.5 Effects on the BCR and NBIR of safety improvement projects as the discount rate reduces

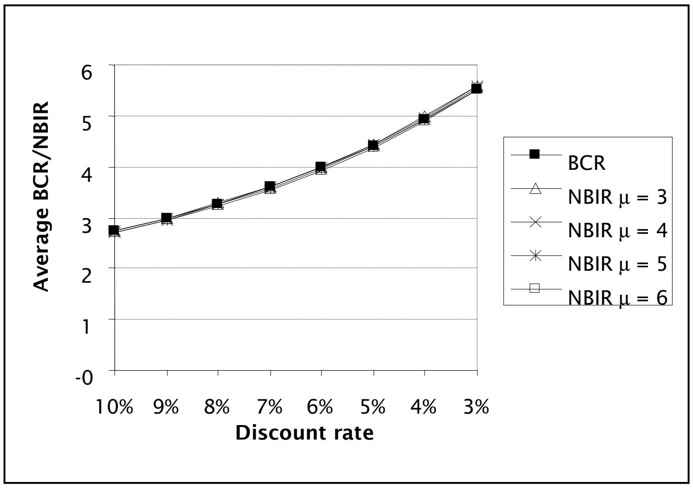


BCRs for safety improvement projects increase on average from 6.1 to 11.5 (an 88% increase).

B6 New and improved walking networks

Figure B.6 demonstrates that variations to the future cut-off BCR have no significant effect on new or improved walking network projects. As the discount rate is reduced to 3%, BCRs increase from 2.7 to 5.5.

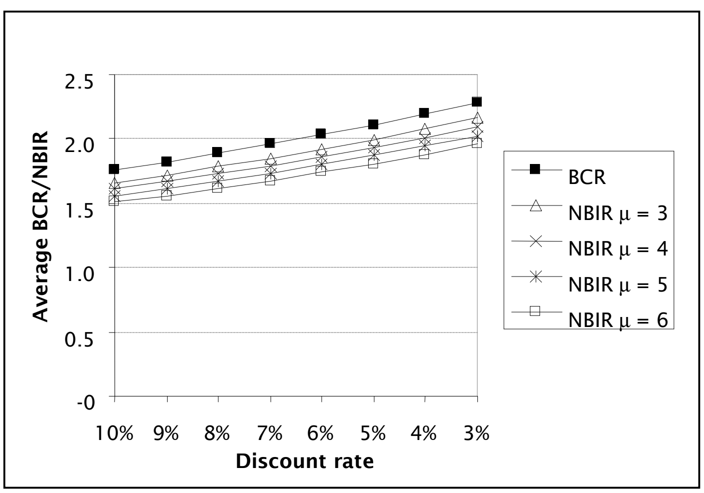
Figure B.6 Effects on the BCR and NBIR of new and improved walking networks projects as the discount rate reduces



B7 Travel behaviour change

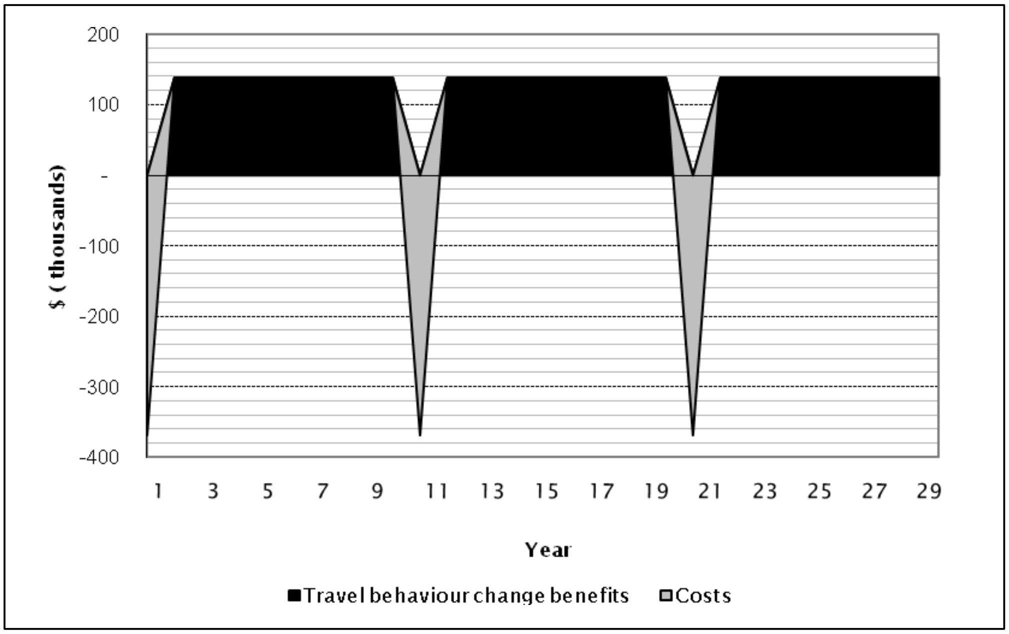
Travel behaviour change projects have an approximately linear improvement in BCR performance as the discount rate is reduced (figure B.7), with the BCR increasing from 1.8 to 2.3, and the NBIR increasing from 1.6 to 2.1 when $\mu = 6$.

Figure B.7 Effects on the BCR and NBIR of travel behaviour change projects as the discount rate reduces



These projects had appraisal periods of 10 years only, and were the only projects that had appraisal periods of less than 25 years. An annual equivalent measure was undertaken to assess the extent to which this reduced approval period governed that result. It did not materially increase the BCRs and the reason why is illustrated in figure B.8. Representing a project as an annuity equivalent is the same as rolling over the project (Boardman et al 2006). These projects lack any growth in benefits, in contrast to all other projects assessed in this study. From what we understand of these travel behaviour change projects, the lack of benefit growth assumed is probably appropriate.

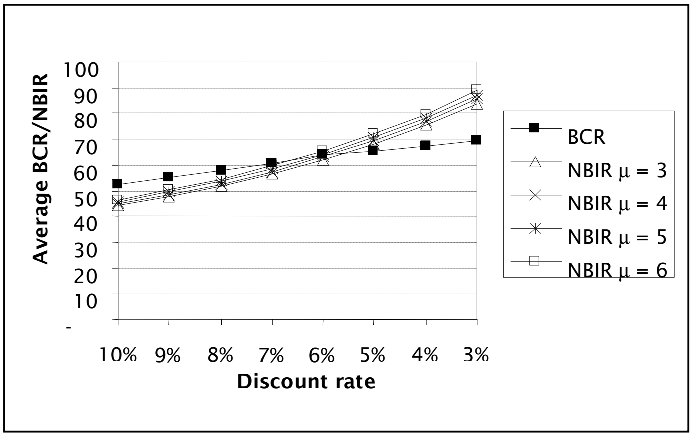
Figure B.8 Time profile of rolling over travel behaviour change projects



B8 Bridge renewals

Evaluations for four bridge renewal projects were obtained. Three were small (an average of $270k in the first year of construction) and the fourth was larger at $2.9m for the first year's construction cost. The BCRs for the smaller three were very high and have the largest effect on the average figures shown in figure B.9.

Figure B.9 Effects on the BCR and NBIR of bridge renewal projects as the discount rate reduces



The average BCR increased from 53 to 69.

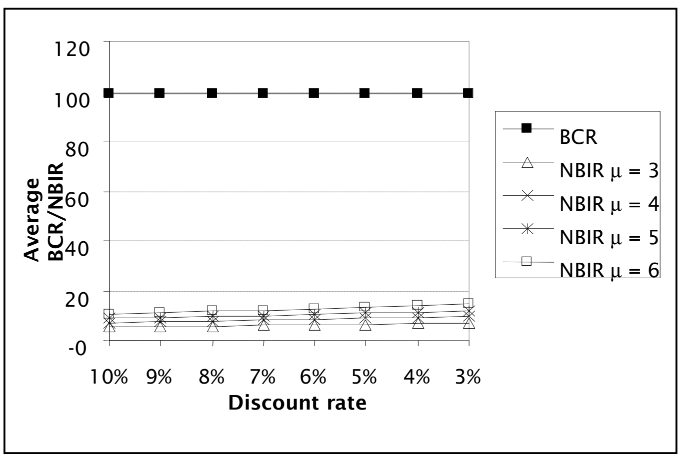
B9 Preventive maintenance

Preventive maintenance projects are initiatives to alter the planned maintenance schedule to lower the 'total cost of ownership' and are funded if they provide any NPV cost savings.

These projects perform better if one also takes account that the marginal BCR will increase as the discount rate is lowered because these initiatives free up funds that can be invested into projects that otherwise would not be undertaken.

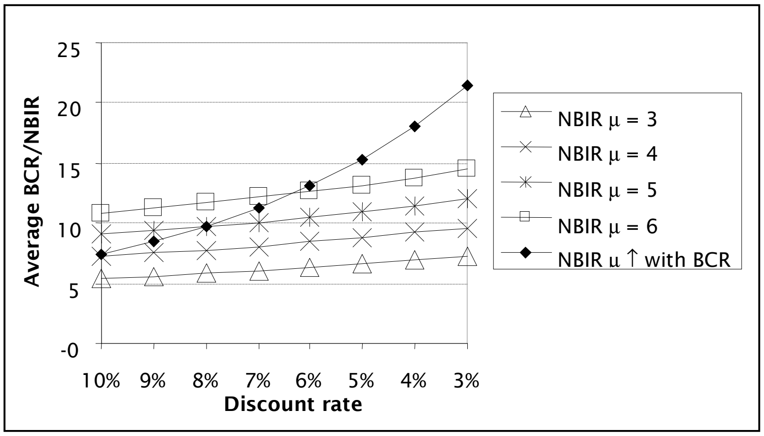
Figures B.10 and B.11 demonstrate the effects on BCRs, with the figure B.10 skewed by the uniform 99 allocated to projects under the standard formulation[33]. Figure B.11 excludes this criterion and shows that NBIR performance mirrors that of NPV. The NBIR performance shows a gradual increase if constant future marginal BCRs are assumed, and a strong increase if marginal BCRs increase in line with motorway BCRs. The NBIR, if *μ* stays at 4, increases from 7.2 to 9.6, and rises from 7.4 to 21 if future cut-off BCRs increase.

Figure B.10 Effects on the BCR and NBIR of preventive maintenance projects as the discount rate reduces



33 Preventive maintenance projects are not assessed using the BCR criterion in practice.

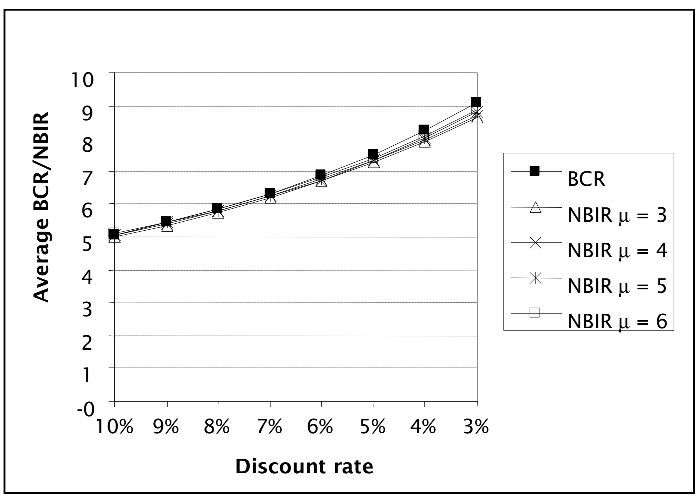
Figure B.11 Effects on the NBIR of preventive maintenance projects as the discount rate reduces



B10 Congestion improvements

The performance of congestion improvement projects is largely insensitive to changes in assumptions about future marginal BCRs. Figure B.12 illustrates how average BCRs increase from 5.1 to 9.1 and average unconstrained NPVs increase from $2.2m to $4.7m.

Figure B.12 Effects on the BCR and NBIR of rural safety realignment projects as the discount rate reduces



Appendix C: Long-term effect of discount rate reductions on BCRs

C1 Projects

This section considers the long-term consequences for BCRs should the discount rate be reduced. The description for motorway construction projects is contained in chapter 12. This section covers rural safety realignments projects, safety improvement projects, bridge renewals and congestion improvements.

C2 Rural safety realignment projects

The two rural safety realignment projects obtained had, on average, a strong increase in projected undiscounted benefits, leading to a sharp cut-off at year 25 even at relatively high discount rates (figure C.1). Extending the last year's net benefit (figure C.2) leads to a relatively large increase in measured benefits at all discount rates.

Figure C.1 Discounted benefit and costs streams to year 25 for rural safety realignment projects

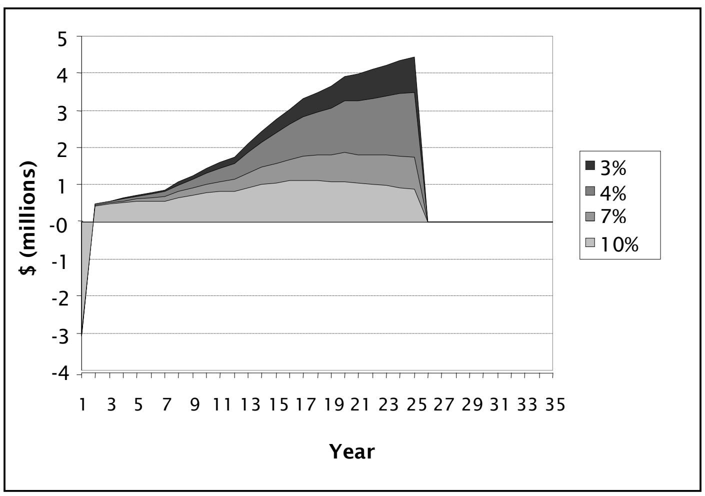


Figure C.2 Discounted benefit and costs streams projected uniformly to year 80 for rural safety realignment projects

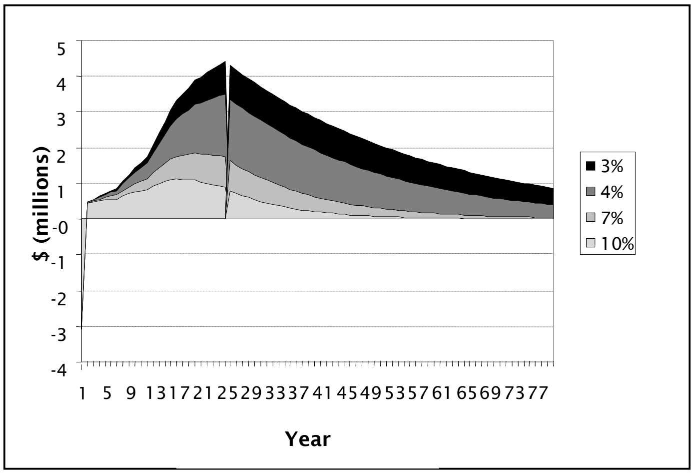


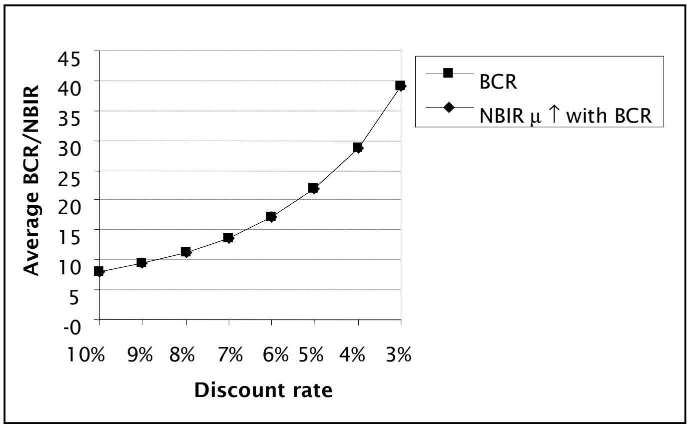
Table C.1 shows that the average BCR increases from 6.0 to 7.9 at a 10% discount rate, and it almost triples at the 3% rate.

Table C.1 Effect of extending the analysis period for rural safety realignments

Discount rate	25-year analysis period		NPV of analysis period years 26–80 (% of 25-year value)	Total with 80-year analysis period	
	NPV ($million)	BCR		NPV ($million)	BCR
10%	17.1	6.0	8.8 (52%)	25.9	7.9
7%	27.5	8.4	24.3 (89%)	51.8	13.7
4%	45.2	12.3	77.4 (171%)	122.6	28.7
3%	53.7	14.2	118.7 (221%)	172.4	39.1

Figure C.3 shows the strong growth in the BCR and NPV as the discount rate is reduced for the extended analysis period. No discernable difference was seen between the BCR and NBIR and the unconstrained and constrained NPV, which supports our prior finding that future budget constraints are not factors in the performance of these projects. (The NBIRs and constrained NPVs in this section again assume that future marginal BCRs equal the BCR of motorway projects.)

Figure C.3 BCRs of rural safety realignment projects – 80-year analysis period



C3 Safety improvement projects

Safety improvement projects have a small, arguably insignificant increase in measured economic performance at the 10% discount rate, but benefits are significant at lower discount rates (figures C.4 and C.5).

Figure C.4 Discounted benefit and costs streams to year 25 for safety improvement projects

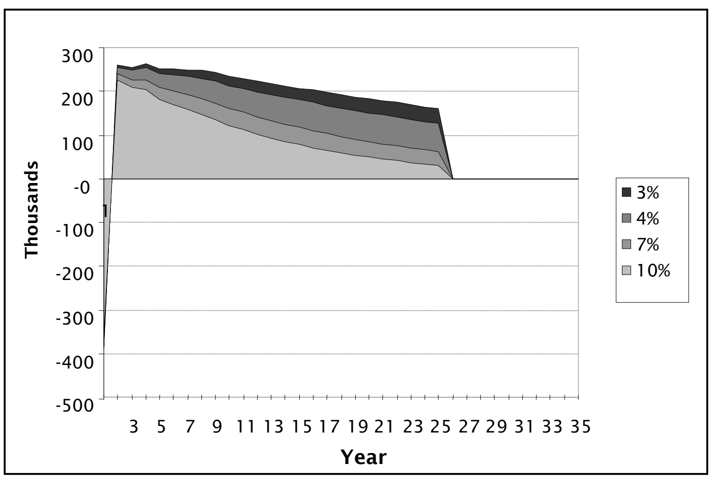


Figure C.5 Discounted benefit and costs streams projected uniformly to year 80 for safety improvement projects

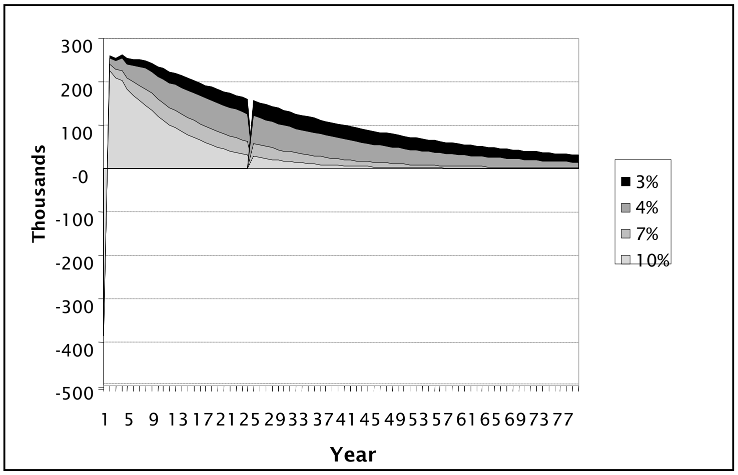


Table C.2 shows that BCRs increase by only 0.8 at a 10% discount rate, but increase more significantly at 7% (from 7.8 to 9.8), and are approximately 50%–100% higher at 4%–3% respectively.

Table C.2 NPVs of safety improvements projects

Discount rate	25-year analysis period		NPV of analysis period years 26–80 (% of 25-year value)	Total with 80-year analysis period	
	NPV ($millions)	BCR		NPV ($millions)	BCR
10%	2.2	6.1	0.3 (15%)	2.5	6.9
7%	3.0	7.8	0.9 (29%)	3.9	9.8
4%	4.2	10.3	2.8 (66%)	7.1	16.6
3%	4.8	11.5	4.3 (90%)	9.1	21.1

C4 Bridge renewal projects

The bridge renewal projects obtained were very strong projects, with average BCRs of 57 even at a 10% discount rate (figure C.6). Significant benefits can be captured by projecting net benefits out to 80 years (figure C.7).

Figure C.6 Discounted benefit and costs streams to year 25 for bridge renewal projects

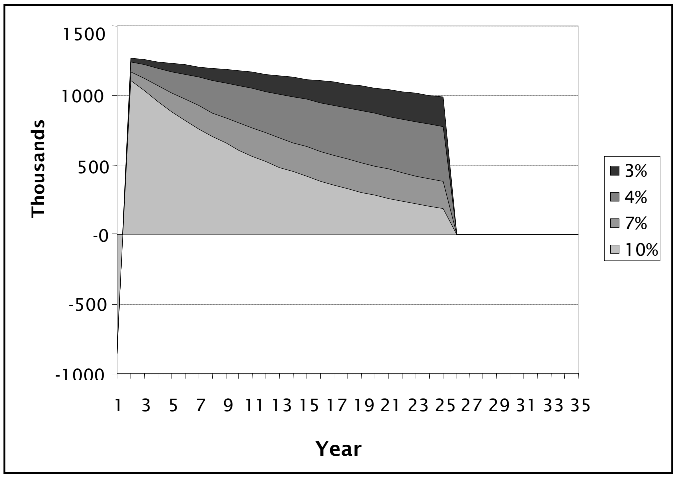


Figure C.7 Discounted benefit and costs streams projected uniformly to year 80 for bridge renewal projects

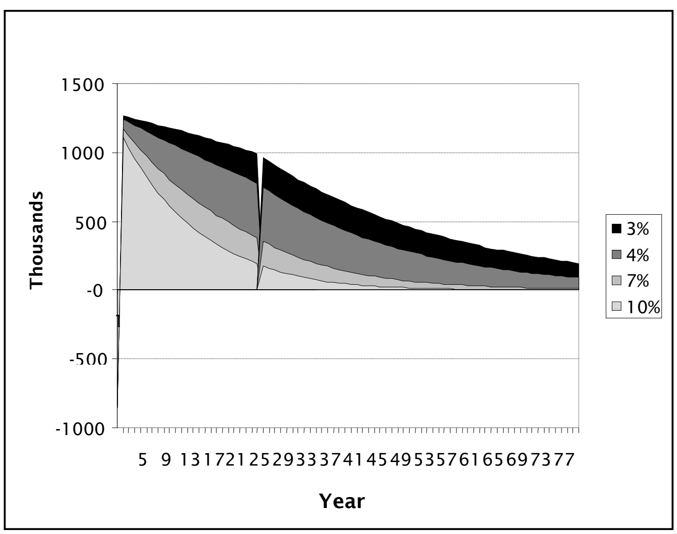


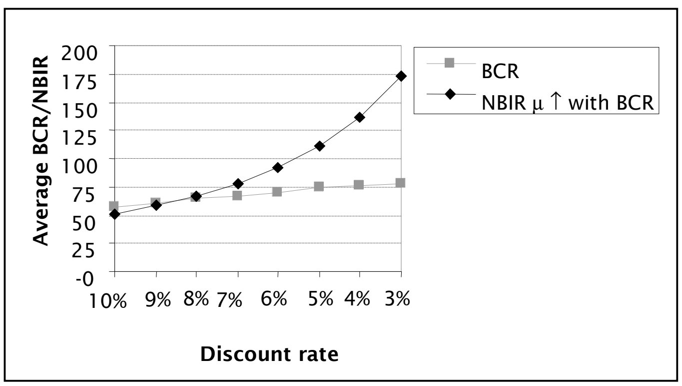
Table C.4 displays the impact on NBIR (a measure that, in this case, assumes the future cut-off BCR equals the BCR of 80-year motorway projects) rather than BCR because BCRs are capped at 99 and do not represent the true mapping of the economic performance indicators.

Table C.3 NPVs of bridge renewals projects

Discount rate	25-year analysis period		NPV of analysis period years 26–80 (% of 25-year value)	Total with 80-year analysis period	
	NPV ($millions)	NBIR		NPV ($millions)	NBIR
10%	12.6	44.9	2.0 (16%)	14.6	51.5
7%	16.9	59.2	5.5 (33%)	22.4	77.1
4%	23.7	82.5	17.7 (75%)	41.4	136.6
3%	26.8	93.6	27.1 (101%)	53.9	172.5

Figure C.8 shows that the NBIR is a more reliable measure as it is less sensitive to the idiosyncrasies of individual projects (one had a negative BCR at a low discount rate because of cost savings). However, the NPV was barely affected by assumptions about future cut-off BCRs.

Figure C.8 BCRs of bridge renewal projects – 80-year analysis period



C5 Congestion improvement projects

Based on the average performance of the two congestion improvement projects obtained, these projects have a modest case for longer analysis periods at lower discount rates (see figures C.9 and C.10).

Figure C.9 Discounted benefit and costs streams to year 25 for congestion improvement projects

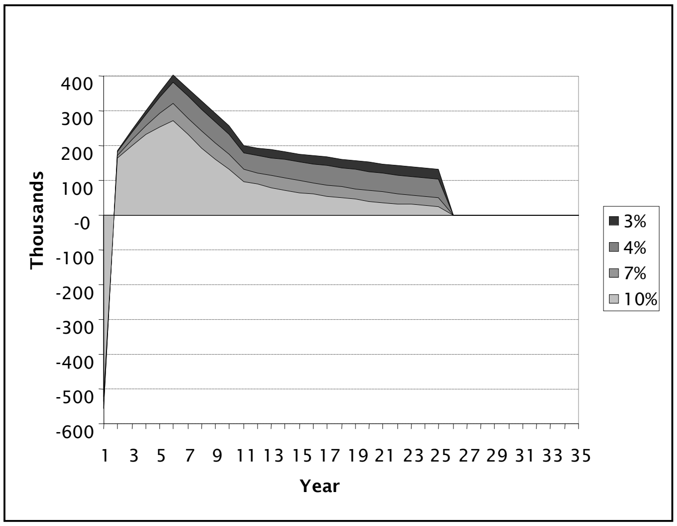


Figure C.10 Discounted benefit and costs streams projected uniformly to year 80 for congestion improvement projects

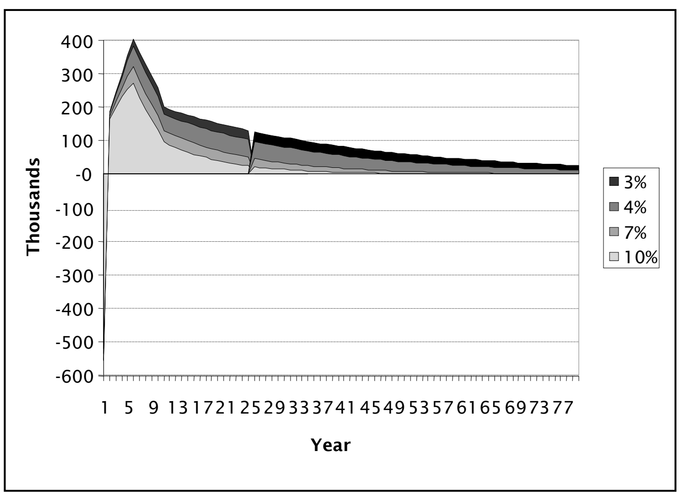


Table C.4 shows congestion improvement projects' average BCR performance increases slightly at 10% from 5.1 to 5.5, has modest improvement at a discount rate of 7% (an increase from 6.3 to 7.6) and increases from 8.2 to 12 at 4%.

Table C.4 NPVs of congestion improvements projects

Discount rate	25-year analysis period		NPV of analysis period years 26–80 (% of 25-year value)	Total with 80-year analysis period	
	NPV ($millions)	BCR		NPV ($millions)	BCR
10%	2.2	5.1	0.3 (12%)	2.5	5.5
7%	3.0	6.3	\0.7 (25%)	3.7	7.6
4%	4.1	8.2	2.3 (57%)	6.5	12.2
3%	4.7	9.1	3.6 (77%)	8.3	15.2

Appendix D: Long-life pavement analysis

Tables D.1 and D.2 show the effects of extending the analysis periods of long-life pavements to a comparable length, which is 76 years for the 160mm pavement and 81 years for the 190mm pavement.

The NBIR of the long-life pavement option is $(\Sigma A2 - \Sigma B2)/(\Sigma B1 - \Sigma A1) = 3.46$.

Table D.1 Cashflow profile of 160mm structural asphalt pavement (2002 dollars)

Description	Amount	10% discount rate		8.296% discount rate		10% discount rate		Code for NBIR workings
		SPPWF/ USPWF	Discounted cost	SPPWF/ USPWF	Discounted cost	μ	Weighted costs	
Cost works ($80/m²)								
1	$80,000	0.91	$72,727	0.92	$73872	N.A.	$72,727	A1
26	$80,000	0.08	$6712	0.92	$10,074	5	$33,562	A2
51	$80,000	0.01	$620	0.02	$1374	4	$2478	
Total construction costs			**$80,059**		**$85,319**		**$108,768**	A2
Cost annual maintenance yr 1			**$500**		**$500**	N.A.	**$500**	A1
Annual maintenance years 2–76	$250	9.530	$2382	11.555	$2889	Variable	$8529	A2
Periodic maintenance costs								
8	$20,000	0.4665	$9330	0.5286	$10,572	3		
16	$20,000	0.2176	$4353	0.2794	$5588	5		
24	$5000	0.1015	$508	0.1477	$738	5		
33	$20,000	0.0431	$861	0.0721	$1442	4		
41	$20,000	0.0201	$402	0.0381	$762	4		
49	$5000	0.0094	$47	0.0201	$101	4		
58	$20,000	0.0040	$79	0.0098	$197	4		
66	$20,000	0.0019	$37	0.0052	$104	4		
74	$5000	0.0009	$4	0.0027	$14	4		
Total periodic maintenance costs			**$15,621**		**$19,516**		$58,014	
Total cost 76 years			**$98,563**		**$108,224**		$175,810	A2

Table D.2 Cashflow profile of 190mm structural asphalt pavement (2002 dollars)

Description	Amount	10% discount rate		8.296% discount rate		10% discount rate		Code for NBIR workings
		SPPWF/ USPWF	Discounted cost	SPPWF/ USPWF	Discounted cost	μ	Weighted costs	
Cost works ($9/m²)								
1	$90,000	0.91	$81,818	0.92	$83,106	N.A.	$81,818	B1
41	$90,000	0.02	$1808	0.04	$3429	4	$7231	B2
Total construction costs			**$83,626**		**$86,535**		**$89,049**	
Cost annual maintenance yr 1			**$500**		**$500**		**$500**	B1
Annual maintenance years 2–76	$250	9.533	**$2383**	11.565	**$2891**			
Periodic maintenance costs								
8	$17,000	0.4665	$7931	0.5286	$8986	3	$23,792	
16	$17,000	0.2176	$3700	0.2794	$4750	5	$18,498	
24	$17,000	0.1015	$1726	0.1477	$2511	5	$8630	
32	$17,000	0.0474	$805	0.0781	$1327	4	$3221	
48	$17,000	0.0103	$175	0.0218	$371	4	$701	
56	$17,000	0.0048	$82	0.0115	$196	4	$327	
64	$17,000	0.0022	$38	0.0061	$104	4	$153	
72	$17,000	0.0010	$18	0.0032	$55	4	$71	
Total periodic maintenance costs			**$14,474**		**$18,298**		**$55,392**	B2
Total cost 81 years			**$100,984**		**$108,224**		**$153,473**	
Extra cost of option			**$2421**		**$0**		**N.A.**	